

METALLURGIA

THE BRITISH JOURNAL OF METALS

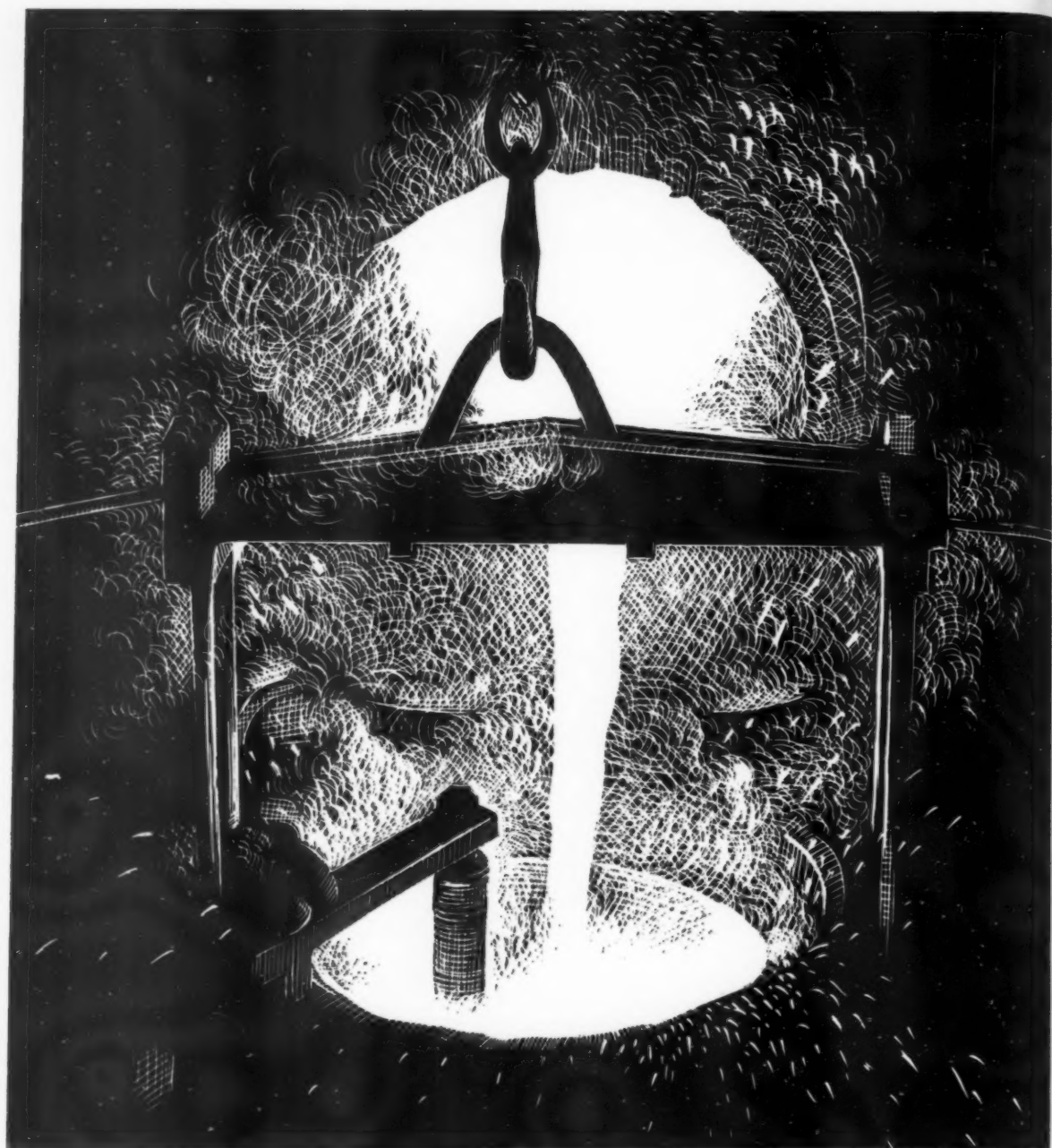
Vol. 47 No. 281

MARCH, 1953

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR MARCH, 1953

Vol. 47

No. 281

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.

Telephone: BLackfriars 2084

London Office:

21, Bedford Street, W.C.2.

Telephone: Temple Bar 2629

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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METALLURGIA

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INCORPORATING THE "METALLURGICAL ENGINEER"

MARCH, 1953

Vol. XLVII. No. 281

Quality Control

ON a number of occasions during the last few years we have drawn attention to the importance in the struggle for export markets of the production of goods of high quality. This term does not necessarily imply luxury goods, or even expensive goods. Rather should it be taken to mean goods which serve the purpose for which they have been designed without appreciable risk of failure; which possess an attractive appearance—and just what is an attractive appearance is governed by the eye of the prospective customer, and not of the manufacturer; and which are not more expensive than seems reasonable taking the foregoing requirements into account. At the same time, there is no point, where orders are dependent on being able to sell at a competitive price, in making products which are "too good," particularly where such a procedure involves the use of expensive or strategically important materials. A compromise solution has thus often to be found, in which the varying requirements of service conditions, economic prices and sales appeal have to be balanced.

A case in point is the finish applied to motor cars; the Americans consider that we are inclined to over-finish cars by giving them what they call a "jeweller's finish" rather than the "kerb-side finish" which is favoured over there. This point was emphasised by Dr. S. Wernick, speaking at the Avery Institute earlier this month, when he made a spirited defence of the efforts of the metal finishing industry in the motor car field. The suggestion had been made that the finish on post-war cars was inferior to that applied before the war, but Dr. Wernick contended that such was not the case. Important developments put into practice just before the war had produced finishes superior to those applied in the early thirties, and finishes on post-war cars, having regard to the high rate of production which was necessary to take advantage of export markets immediately after the war, together with the baneful restrictions on the supply of nickel with which the industry had been faced, had been well up to standard. Nevertheless, Dr. Wernick agreed that there was no room for complacency, and that finishing had never been so important as to-day.

In view of the acknowledged importance of quality—in other fields as well as finishing—the Productivity Report on Inspection in Industry, which was published last month, will be read with interest, because the team has considered inspection on the wider basis of quality control, and has studied and discussed mainly the inspection function and the organisation required for its performance, in the belief that such treatment will be of greater benefit to others than would a catalogue of detailed differences in procedure and practice between Britain and the United States. As have so many of its predecessors, the team concludes that the best British

practice is not behind the best in America, but that there is not the same enthusiasm over here as is revealed by the attendances at the meetings of the American Society for Quality Control.

Inspection is primarily a management function, as in all fields of management, and at all levels, it is not enough merely to set up an organisation to carry out a process; there must be a continuous check that the organisation is fulfilling its purpose. Some firms have seen fit to impose on top of an existing inspection department, a so-called quality control organisation, one of whose functions is to inform top management straight from the factory about current quality, just as it is usually informed about quantities and costs. Only with this added information can management effectively make the right decisions. Such a quality control department would have duties other than those of reporting. Market and other outside factors affecting quality could be channelled through this department to exert their influence on design and production, whilst production troubles requiring rather longer-term investigation than can be undertaken by the inspection department would fall to it for solution.

The belief is expressed by the team that the influence of well-planned quality control organisations within industry can have far-reaching effects on the national economy. Not only is the work of an individual operative rendered more effective; not only are materials used more effectively; not only does the organisation within the firm run more smoothly; but the nation as consumer is presented with an article more suited for its work, less liable to fault, and having a more precisely determined life. It is the existence of variability which militates against all these advantages, and it is with variability that inspection is designed to cope.

The recommendations of the team fall into two categories: those of a general or national character which require group or national action, and those outlining the steps to be taken by firms wishing to employ the most modern techniques. In the former class is strong support for the establishment of a technical qualification in inspection, based on a syllabus which should include simple statistical methods in addition to metrology and organisation. The importance of statistical methods is further emphasised in a number of other recommendations urging the organisation of training courses in such subjects as statistical engineering and statistical quality control.

A further suggestion is made that, in view of the widespread activity and recent growth of the American Society for Quality Control, the professional institutions in this country could make a contribution to increased productivity by providing more specific opportunities for discussions among their members about the control of quality. This suggestion is particularly interesting in view of the arrangements made by the Institute of Metals to hold, in connection with the Annual General

Meeting this month, an all-day symposium on the control of quality in melting and casting non-ferrous metals. This is the first of a series covering the control of quality in the production of wrought non-ferrous metals.

Management has a big part to play in quality control. It should first clearly define the standard of quality to be attained, and then set up an organisation, commanding both respect and co-operation to ensure the standard is maintained. Perhaps most important of all, it should, by all the means in its power, endeavour to create an atmosphere in which everyone, especially production operatives, is quality-conscious.

Flame Radiation Research Institute of Fuel Discussion

INTRODUCING a discussion before The Institute of Fuel in London last month on the work of the Flame Radiation Research Joint Committee, PROFESSOR O. A. SAUNDERS (Chairman of the British Committee) said that the aim of the investigations at Ijmuiden, Holland, was to improve the efficiency of industrial furnaces. Results obtained to date by the team of young British, French, Dutch and Swedish scientists had led to a better understanding of heat transfer processes—in particular of heat transfer by flame radiation.

Heat transfer by radiation from luminous flames was mainly due to suspended carbon particles. We lacked knowledge of the number and size of these particles, and their rate of formation. The problem was a complex one, and could not be studied satisfactorily in the laboratory; investigations were needed on a scale approaching that of the furnaces actually used in industry. Such investigations had been carried out at Ijmuiden over the past four years.

MR. M. W. THRING (General Superintendent of Research to the Committee) said that the earlier experiments were of two types—"performance trials" and "combustion-mechanism trials." In the performance trials the effect on the flame radiation of the following pairs of variables was compared: (a) oil and creosote pitch; (b) rate of fuel energy input, 76 and 106 therms per hour; (c) air and steam as atomising agents; (d) an increase of 20% in the quantity of atomising agent; (e) an increase of 25% in the quality of combustion air. In the combustion-mechanism trials the object was to measure in great detail the conditions inside the flame, with a view to finding an explanation of the results of the performance trials. For example, the structure and distribution of the soot particles in flames had been studied by means of the electron microscope.

In the second series of experiments (the "burner trials") the effect on the flame characteristics of using various types of burner was studied. At first the experiments were confined to oil fuel, but later comparison was made between coke-oven gas and oil as fuel. It was shown that (1) in the early part of the flame the radiation from coke-oven gas is much lower than for oil; (2) in both cases the most important effect on flame radiation is that of jet momentum; and (3) the emissivity of the flame depends on the square of the soot concentration, if the soot is formed by two molecules meeting.

The next stage in the work would be to apply the new knowledge concerning the effect of jet momentum on flame length, and the relative effects of air and steam

as atomising agent, to improving burner design. And studies would be made of the radiation from pulverised-fuel flames in water-tube boilers.

Following Mr. Thring's address there was a general discussion, in which the following were among those who took part: DR. J. H. CHESTERS (United Steel Companies), SIR CHARLES GOODEVE (British Iron and Steel Research Association), MR. G. J. GOLLIN (Shell Petroleum Co.), MR. I. LUBBOCK, DR. G. W. C. ALLAN (British Coal Utilisation Research Association), and DR. A. PARKER (Director of Fuel Research, D.S.I.R.).

New Home for B.S.I.

THE British Standards Institution recently announced to its 7,800 subscribing members that it will move at the end of the summer into a single, self-contained office block at 2, Park Street, Mayfair. It is well over half-a-century since the B.S.I. occupied its first office at No. 28, Victoria Street, London. Today the Institution spreads over seven floors of the same building and the adjoining No. 24. It also occupies extensive accommodation at 24, Gillingham Street, a mile away behind Victoria Station.

Although the floor-space at "British Standards House," as the new home is to be called, is not substantially greater than that at present occupied by the B.S.I. concentration of the staff and facilities under one roof will aid efficiency and economy: and space will also be available for all the 3,800 committee meetings which the B.S.I. convenes in the course of a year. The many thousands of industrial and professional people in practically every major field of industry, who devote so much time to serving on B.S.I. technical and policy committees, will find added convenience in this centralisation.

The Institution's work and responsibilities are still rapidly expanding, as evidenced by the fact that nearly a million copies of British Standards are sold in a year—and more than a quarter of them overseas. Some 250 new and revised standards are prepared each year, and now the Institution is engaged in the preparation of quality and performance standards for the wide range of clothing, furniture and other domestic equipment which was formerly covered by the Utility schemes.

The new building will not only provide an appropriate and dignified home, but will also enable the Institution's services to be more efficiently operated in the interests of its members and of industry in general.

International Instrument Congress and Exhibition

THE First International Instrument Congress and Exhibition, sponsored by the Instrument Society of America, will be held in September, 1954, in the Philadelphia Museum and Convention Hall, Philadelphia, Pennsylvania, U.S.A. The Congress will open on September 13th and close on September 25th, the Exhibition being open September 15th to 21st.

A number of societies and associations have tentatively decided to co-operate in arranging the meeting, and invitations will be extended to instrument users throughout the world. Space is available to any company manufacturing instruments and laboratory apparatus for measurement, analysis, inspection, testing, computing, photography and automatic control.

Some Metallurgical Applications of Ultrasonics

By Alan E. Crawford, A.R.Ae.S.

(Mullard, Ltd.)

The contribution made by ultrasonics to one solution of the problem of soldering aluminium is well known, and the resultant method is now in everyday use in the workshop. In this article, the author discusses the factors governing the design of ultrasonic generators for metallurgical applications, and refers to a number of ways in which ultrasonics can be used, particularly in the foundry.

THE use of high power ultrasonic waves in metallurgy has been studied for some time, but until recently work has been handicapped by the absence of suitable generators for research and subsequent production exploitation. The introduction of reliable equipments employing magnetostriction transducers now opens up this new field of application, and it is already showing promise in a number of processes in the foundry, in electroplating, and in metal fabrication.

Generators

Ultrasonic waves can be produced by many different types of generators and transducers, but, with the exception of magnetostriction units, all have considerable disadvantages when it is necessary to propagate the sound wave into materials at elevated temperatures. It is usually impossible to couple the transducer directly to the material, and a coupling bar is, therefore, required. The use of crystal transducers makes the acoustic coupling between the bar and the crystal a difficult procedure and liquids are usually employed as a means of providing such a coupling. Crystals are also affected by changes in temperature, and this factor imposes limitations on their employment in the metallurgical industry.

Magnetostriction transducers, however, are inherently robust in form and can be connected to coupling rods by soft or hard soldering. The characteristics of the material used enables them to be employed as an ultrasonic source at elevated temperatures, and the generators required for driving purposes are simple in form and can be operated by relatively unskilled personnel.

Magnetostriction

The little-utilised effect of magnetostriction has been known and observed for many years, but it is only comparatively recently that satisfactory explanations have been given for the reasons a material exhibits this effect. All magnetic materials are magnetostrictive to a greater or lesser degree, and are characterised by a change in their physical dimensions when they are placed in a magnetic field. Similarly, there is a change in magnetisation in such materials when their dimensions are altered by an external force. The ferromagnetics—iron, nickel, and cobalt, and alloys of these metals—are all magnetostrictive. Several different effects have been noted, but the change in length along the axis of the applied magnetic field when the field is varied is the only one that need be considered for ultrasonic generation. This is usually termed the "Joule" effect.

Magnetostriction can be explained by consideration of the domain theory. In an atomic system, the fundamental particle is the orbital electron. However, in most systems the magnetic effects produced by orbital movement nearly neutralise each other. Due to the random orientation of atoms in a solid, the magnetic moments of separate atomic groups are generally cancelled out. There are certain exceptions, however, and these occur in the materials known as ferromagnetics. In these systems, a force exists which causes the atomic magnetic fields to lie parallel and these domains of magnetic moments can be aligned by an external magnetic field. Each domain is magnetised to saturation but, dependent on the crystal structure of the material, may be in any of a number of fixed directions known as the "easy directions of magnetisation."

With an increasing external magnetic field, certain of the domains that were originally magnetised in the direction of the field grow in size, taking over the other differently oriented domains until the complete crystal becomes one large domain. As the field becomes more intense, the domain in each crystal rotates until it is parallel to the field. During this process, the material expands or contracts its external dimensions and continues to do so until all the domains are parallel. The material is then said to be saturated.

It should be appreciated that the changes in dimensions are very small. Nickel shows one of the largest changes in unit length, but this actually amounts to only 30 parts in a million. If the material is at mechanical resonance with an alternating field, the change may be as high as one part in a thousand, but will be limited by fatigue properties of the material. The static force produced will be determined by the change in length and the modulus of elasticity of the metal: for nickel this is in the region of 1,000 lb./sq. in.

The ferromagnetic materials differ widely in the magnitude and sign of the magnetostriction effect, as is shown in Fig. 1. It will be seen that iron expands in a weak field and contracts in a strong field, whereas nickel contracts at all field strengths. As the temperature increases, the material loses its magnetostrictive properties and continues to do so until the Curie point is reached.

Pure nickel is commonly used for the construction of ultrasonic transducers, but has some disadvantages for certain applications. It possesses a Curie point of 360° C. and will, therefore, require adequate cooling facilities if it is employed for metallurgical applications utilising heat. The resistance to fatigue is also low in comparison with

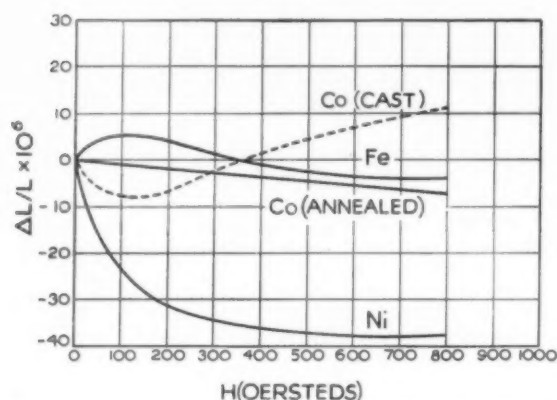


Fig. 1.—Change in length per unit length with varying field strength for iron, nickel and cobalt.

other metals. An interesting material for certain magnetostriction purposes is found in the nickel-iron alloy system. Fig. 2 gives curves for the change in length as a function of induced magnetism ($B-H$) for various alloy proportions¹.

The iron-cobalt alloy known as Permendur has very large magnetostriction factors. Small percentages of vanadium are added to ensure workability of this material, which possesses a high Curie point and excellent fatigue resistance. Current commercial designs of transducers are now using this material for applications where heat is experienced; the Mullard ultrasonic soldering iron is a typical example.

It will be seen that the effect occurs in the same direction for a given material, irrespective of the polarity of the external field. If a sine-wave source is used to energise the exciter coil, the frequency of the dimensional change will be twice the exciting frequency. To avoid this, it is necessary to provide an initial magnetising bias of a magnitude that is not exceeded by the exciting field. In practice, a magnetic bias is chosen where

$$\frac{\Delta S}{\Delta B} \quad (S=\text{strain and } B=\text{biasing flux density})$$

will be a maximum. This point can be selected approximately by a consideration of the static curves, and has been found to be that at which the biasing flux density B equals about 60% of the saturation value. This can be supplied by permanent magnets or, more conveniently, by a direct current in the energising coil.

The resonant frequency of a magnetostriction element can be expressed as

$$F = \frac{V}{2L}$$

where V is the velocity of sound in the material, and L is the longitudinal dimension of the element. In most materials, the velocity of sound varies slightly with the temperature of the medium, and this must be taken into consideration in the design of transducers for operation in heated conditions.

Early magnetostriction elements utilised nickel rods or tubes, but they suffered from the disadvantage of high eddy current losses and low fatigue resistance. Attempts to cut down losses by slotting the tubes have been made, but this further weakens the fatigue resistance. Laminated assemblies similar to transformer cores are

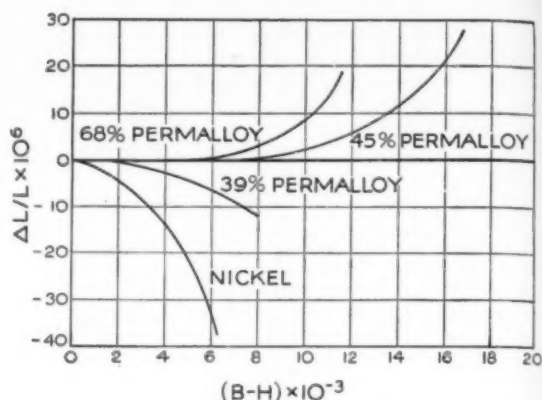


Fig. 2.—Change in length per unit length as a function of induced magnetism for nickel-iron alloys.

now used, the laminations being insulated from each other by an oxide coating on the metal, or by mica inserts. This effectively cuts down electrical losses and gives a structure which has a high fatigue resistance.

Power Units

The power supply for a magnetostriction transducer consists basically of a power amplifier fed by a variable-frequency sine-wave source and a D.C. current supply for polarising purposes (Fig. 3). The amplifier is similar electrically to a normal audio unit as is employed for public address purposes, but is provided with an output-matching transformer that is capable of high efficiencies at the frequencies used, and that can be matched to the transducer impedance. In the frequency range 20–30 kc/s, it has been found that efficient transformers can be designed using manganese zinc ferrite cores instead of the usual iron cores. The amplifier is driven by an oscillator adjustable over the range 15–40 kc/s. When transducers are mechanically coupled to solids, their natural resonant frequency will be altered and the oscillator is tuned to match this frequency to achieve maximum ultrasonic output. Fig. 4 shows a Mullard generator of this type.

Transducers

For ultrasonic propagation into liquids at normal temperatures, the coupling of the transducer to the work presents no great difficulty. Usually the magnetostrictor can be completely immersed in the liquid, or the active face can be maintained in contact with it. If the liquid is capable of wetting the surface, no large acoustic impedance is presented by the interface and propagation takes place with little acoustic loss. It will be realised that, as a sound wave is essentially a particle movement, the acoustic coupling required is of the utmost importance

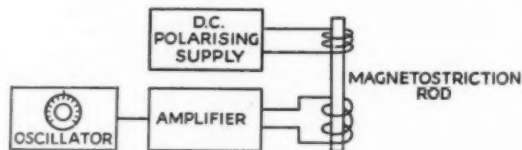


Fig. 3.—Basic diagram of magnetostriction ultrasonic generator.

if high transfer efficiencies are to be achieved. In the metallurgical industry, however, a number of problems are encountered that are not met in other applications of ultrasonic energy. Usually the material under treatment is at a high temperature, and in many cases it is not practicable to position the transducer close to the work. In the case of the grain refinement of cast metals, the metal must be allowed to solidify while in contact with the transducer face, and it may be necessary to consider the transducer consumable if a welding action occurs. A coupling rod with matching acoustic characteristics is, therefore, employed, and many types and materials have been suggested and tried. The joining of this rod to the transducer face is one problem that has not been satisfactorily solved for universal applications.

For many purposes, the system shown in Fig. 5 can be employed. A stack transducer of square cross section, and wound with glass-insulated wire, is brazed to the end of a coupling rod whose length has been adjusted to be a function of the wavelength of sound through the material, and is mechanically resonant at the frequency employed. Generally, a bar with a half-wavelength resonance is used, and this means that there is a node of

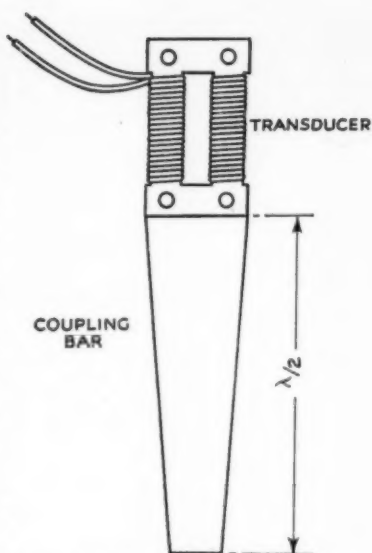


Fig. 5.—Transducer fitted with coupling bar.

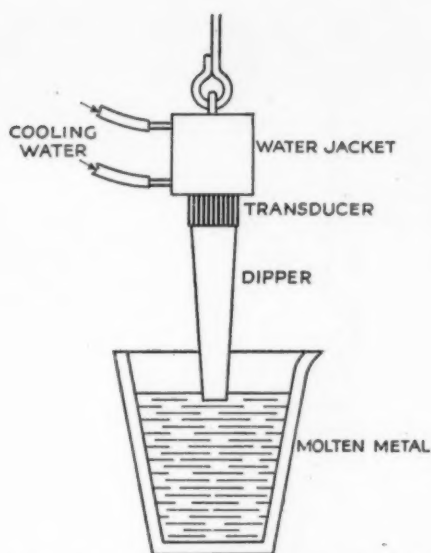


Fig. 6.—Treatment of metallic melts by low frequency ultrasonic energy.

vibration at approximately the physical centre, and an anti-node at either end. Clamps, if needed, can be positioned at the nodal point without damping the bar, thus enabling the unit to be rigidly positioned for coupling to the work. In some applications, it is necessary to use high acoustic energy concentrations, and this can be effected by tapering the bar; the amplitude at the operating face will then be a function of the ratio between the diameters of the ends of the bar, increasing as the operating face diameter decreases.

German publications have suggested demountable bars, using a liquid interface of oil or grease². The bar and the transducer are clamped together by members positioned at their respective nodal points. The material used for the bar can be mild steel for many applications, but when used for treating molten metal the choice of material will be governed by the metal being melted, so that pick-up of impurities from the coupling bar can be avoided. Quartz and graphite rods have been used with some success, a joint being made to the magnetostrictor with a resin cement such as Araldite. It is then necessary to provide cooling for the transducer and joint if high temperatures are experienced.

APPLICATIONS

Metallic Coatings

The use of ultrasonic waves to facilitate the coating of metallic surfaces with other metals is now well known, and has been discussed in detail in other papers when used for the specific purpose of soldering³⁻⁵. It is of interest, however, to note that the process is not restricted to low melting point coatings; steel can be coated with aluminium, for example. Further work is required in this direction, but there would appear to be possibilities in the simplification of existing coating methods with improved results. The lowering of surface tension produced under ultrasonic treatment promotes a smoother flow over the surface, with a greater freedom from flaws and uneven thicknesses.

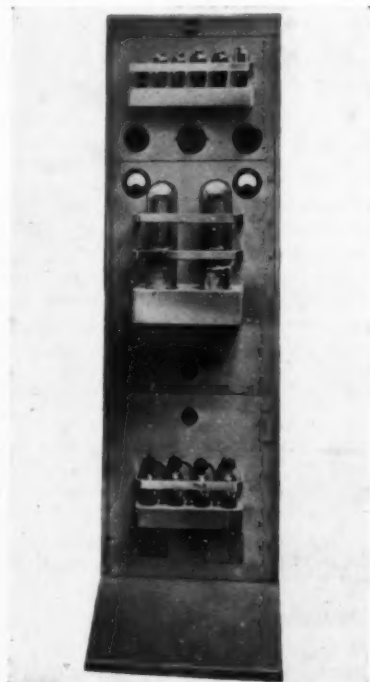
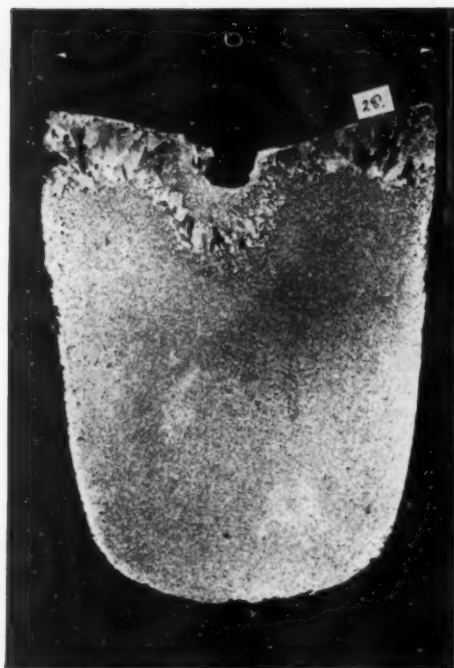


Fig. 4.—Mullard 1 Kw. ultrasonic generator for driving a magnetostriction transducer.



(a)



(b)

Courtesy of the Physical Society.

Fig. 7.—Melts of aluminium-4%-copper alloy. Weight 20 lb. (a) Solidified normally. (b) Solidified during ultrasonic irradiation.

Grain Refinement

The problem of grain refinement in metal casting is well known, and a number of processes for improving the crystalline structure are employed. Success has been achieved in this direction by the employment of ultrasonics during the solidification period, and the work has been reported in a number of papers⁶⁻⁸. Fig. 6 shows the basic arrangement for irradiating the melt: this system has been used with success on aluminium alloys. The photographs in Fig. 7⁹ show the effect on an aluminium-4%-copper alloy using about 100 watts at 26 kc/s. It will be noted that the dendrites in the microstructure are broken up and dispersed, and it is thought that grain size reduction is produced by the shattering of newly-formed dendrites in the metastable region during solidification, thus producing new dispersed nuclei for the growth of smaller crystals. Similar results have been noted with antimony and cadmium and various alloys of aluminium and magnesium. In the case of antimony, it has been reported that there is a considerable increase in the hardness of the metal. It is also stated that undercooling is eliminated, but the time for solidification is not reduced.

Degassing

The degassing action of ultrasonic waves is known for liquids at normal temperatures, and has also been applied to molten metals. Recent papers have claimed that equivalent results to those obtained by the use of chlorine are possible, vibrations being applied to the melt at about 50°C. above the liquidus and maintained until solidification occurs. Suspended particles or bubbles of gas tend to collect at the nodes of a wave in a

liquid and thus will coalesce into a bubble large enough to rise to the surface and disperse.

Segregation and Dispersion

At low ultrasonic intensities, below the cavitation threshold, there is a tendency for separation to occur in metallic melts. In the aluminium-silicon alloys, the silicon content can be brought to the top by applying ultrasonic waves. This has also been noted in the aluminium-copper series up to the aluminium-33%-copper eutectic.

When the wave is of sufficient intensity to produce cavitation, the opposite effect of dispersion occurs, and this has been used to mix powdered metals into melts and to produce alloys of normally immiscible metals. The production of alloys of aluminium and lead, aluminium and cadmium, and iron and zinc has been effected by this method. Increased solubility of normally alloying elements has also been noted, and the increase in the solubility of carbon in iron has been reported in detail. Many of these alloys differ widely from a true melt as it is not necessary to raise the mixture to a temperature where both materials are in a molten state. The complex alloy FeZn, has been produced by this means, by melting zinc in an iron crucible and treating with ultrasonics during the molten stage. The use of the large pressures produced in an ultrasonic wave has been employed to promote crystallisation of carbon in iron, and thus to synthesise diamonds.

Miscellaneous Effects

It has been noted that if a metal is subjected to ultrasonic vibrations in a solid state it becomes more

active in the presence of chemical reagents. Interesting experiments have been conducted on the nitriding of steel under these conditions, and it has been reported that the process is considerably accelerated. The attack by chlorine on many metals has also been speeded up. Diffusion of hydrogen through heated platinum is modified under the action of ultrasonic waves, the temperature necessary for the action being very much less than that normally required. It is possible for active diffusion to take place at room temperature using high vibratory intensities. It is thought that the molecules in a solid behave under intense vibration in the same way as if the solid were heated, increasing the spacing between them and allowing the passage of diffusing gases.

The allotropic transformation of white tin, with a tetragonal structure, into grey tin of cubic structure has been observed to be accelerated by the action of vibration and low temperature. Provided that the tin is lowered to a temperature of 12° C.—the point of reciprocal trans-

formation of the two allotropic modifications—the application of ultrasonics can start the transformation. The reverse will occur at temperatures above 12° C. changing grey tin to white tin.

Many other miscellaneous effects have been listed and the whole subject requires considerable further work directed towards the application of ultrasonics in production techniques. The effects outlined tend to show the extent of the field that can be covered and the introduction of efficient generators is rapidly stimulating active research into a number of applications.

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Open-Hearth Steel Furnace Maintenance Proceedings of Conference Reported

A further conference has been held to discuss the findings contained in the Productivity Report on Iron and Steel. This time the repair and maintenance of open-hearth furnaces was the subject and papers were presented dealing with practice in Britain, Germany and the United States. A brief account of the proceedings of the conference is presented here.

THE maintenance and repair of open-hearth furnaces was the subject discussed at a recent joint meeting of the Iron and Steel Institute's Engineers Group with the Plant Engineering and Steel-making Divisions of B.I.S.R.A. This conference was one of a number being organised in the industry to discuss the findings of the Productivity Report, published last June, one of whose principal conclusions was that less maintenance man-hours are expended in America, despite harder furnace driving, and repair times are shorter.

British practice was discussed in the morning session, with Mr. J. F. R. Jones (John Summers & Sons, Ltd.) in the chair; overseas practice was discussed in the afternoon session with Dr. T. P. Colclough, C.B.E. (British Iron and Steel Federation) in the chair. The papers in the morning session were:

Cold Metal Practice: Fixed 80- to 100-ton Furnaces. By J. E. PLUCK, Steel Peech and Tozer.

Hot Metal Practice: 80-ton Fixed and 250-ton Tilting Furnaces. By S. G. WILLIAMS, Guest Keen Baldwins Iron and Steel Co., Ltd.

and in the afternoon session:

Repair and Maintenance of Open-Hearth Furnaces in Germany. By DR.-ING. C. KREUTZER and DR.-ING. A. MUND, Maerz Offenbau G.m.b.H., Krefeld, Germany, which was presented by DR. MUND.

Repair and Maintenance of Open Hearth Furnaces in U.S.A. By R. W. EVANS and I. S. SCOTT-MAXWELL, Steel Company of Wales, Ltd.

Cold Metal Practice

MR. J. E. PLUCK confined his remarks chiefly to practice at the Templebrough melting shop at Steel

Peech and Tozer, where there are 14 furnaces of 80 tons capacity, all recently converted from producer gas to oil fuel, and now in the process of being rebuilt, one at a time, to 100 tons capacity.

The intention was to work 11 furnaces throughout, and as the plan was based on roof life, and roof life averaged 12 weeks (patched if necessary to attain the average), one furnace must go back into operation each week, whatever the duration of the repairs on the three currently down. The speaker laid emphasis on the fact that in planning major repairs, very careful attention was given to examination after shut down, the length of the campaign and the last major repair history, which together enabled a forecast of the necessary repairs to be made.

Top repairs were carried out after 12 weeks (one roof life) and general repairs after a campaign (a checker life) which was usually two roof lives. In a top repair, all the furnace above the sill and the slag (which was very solid) were removed, and all the brickwork was rebuilt. This normally took a week, which was sometimes exceeded because of the necessity of including some checker and uptake repairs, which, in turn, was a consequence of improved roof life on some furnaces. A general repair was similar to a top repair with the addition of checkers and flues. That is, the checkers were taken out and replaced, flues cleaned out, furnace roof, front and back walls, tap hole, bath banks, burner block ends, ramp roofs, uptakes and all the slag pockets were dismantled and rebuilt, and the slag pocket arches bridge wall, and neck and checker arches given any necessary repair. The speaker described the detailed organisation of a general repair, which lasted two weeks.



Tractor shovel entering slag pocket to remove rubble and blasted slag at East Moors works.

Warming up took three days after each type of major repair, in both of which the men employed were :

Dismantlers : three shifts of 12 men and one charge-hand on each shift = 39 men.

Bricklayers : three shifts of 12 bricklayers and 13 labourers and a chargehand on each shift = 78 men.

For maintenance and repairs during the campaign, a hot repair gang of bricklayers was employed, who also relined ladles : roof patching was often necessary after eight or nine weeks. If, towards the end of the campaign, the furnace was draughting badly, then a false flue was sometimes built through the checker wicket and through the manhole into the flue, thus slightly short circuiting the checkers. This could be effective on a pitch-cresote-fired furnace, and might give an extra week's production. Replacement of a full new main roof and front wall because of accident would take about three days. Repair due to bath breakout might take anything from two to ten days.

On the question of brick supplies, Mr. Pluck said that his works used an average of 214,000 per week, of which 144,000 were used on top and general repairs—over 100 wagons per week, or about 16 per day, and of these, 75% were unloaded direct on the furnace site. Railway wagons in this country were not suitable for pallet loading, and they did not use it. He thought that to make pallet loading practicable it would be necessary to have wagons with 6 ft. wide doorways, access from each end and room on the wagons for a fork-lift truck to turn round. In addition, very large brick storage was necessary, as well as complete road transport accessibility, which was only possible on new sites. Refractories consumption averaged 60 lb. per ton of steel on furnaces with silica roofs ; 35 lb. on all-basic furnaces.

Average roof life had improved over the last six years (Table I), with a slight check in 1947/48 when the extended working week was introduced. The big

TABLE I.—ROOF LIFE AT STEEL PEECH AND TOZER.

Year	Actual Casts	Life Weeks	Rate of Working (Casts/Week)
1946	126	10.6	11.9
1947	114	9.7	11.8
1948	126	9.6	13.1
1949	129	9.7	13.3
1950	157	13.0	13.0
1951	185	13.6	13.6

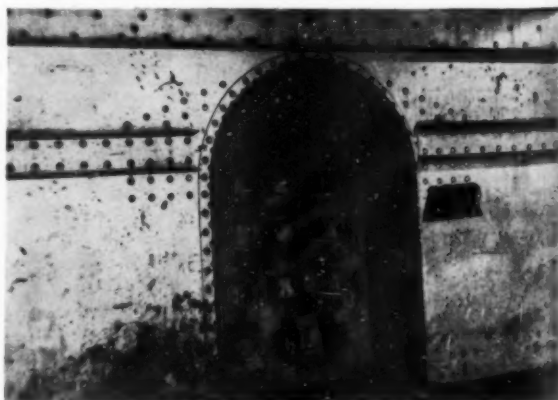
increase in roof life in 1950, accompanied by a slight drop in the rate of working, was mainly due to the beginning of trials with low-alumina silica bricks. The very marked improvement in 1951 was due to a number of factors, including super-duty bricks, teamwork, the use of roof pyrometers by the furnace crews, and a reduction in the number of special repairs. Low-alumina bricks gave excellent results when used for full roofs, but proved uneconomic. They were now used profitably where there was most wear.

Hot Metal Practice

Mr. S. G. WILLIAMS, describing "Hot Metal Practice: 80-ton Fixed and 250-ton Tilting Furnaces," said that at the East Moors works they had five tilting and two fixed furnaces. The shop had been operating over the last three years at a figure of 87% furnace availability, equal to the continuous production of six out of the seven furnaces. It was hoped to increase these figures to 93% and 6.5, respectively, within the near future.

They did not employ a separate hot repairs crew, so careful scheduling was essential, as was good intelligence of the state of all furnaces and thorough records of previous repairs. A three-monthly repair programme was laid down, and in order to ensure that bricklayers were not required for a hot repair at the same time as they were wanted on a general repair, the beginning of a general repair sometimes had to be delayed.

A factor which had contributed to increased campaign life was the use of bonded instead of ringed roofs, which took one shift longer to install, but had reduced patching and practically eliminated collapses. Another factor was the use of basic bricks at furnace ports, front and back linings, wing and side walls, and uptakes to charging floor level. Possible heat loss, however, through 9 in. uptake linings had determined a return to 14 in. thickness. Mr. Williams remarked in this connection that they could now keep a continuous record for six hours of the air temperature and waste gas temperature, and might be able to do so for 24 hours if necessary. He had found that checker temperature was a very poor guide to the air temperature, which optical pyrometers on the checkers had shown to differ by as much as 150°-200° C. The use of basic brick, with added protection from a 3 in. splay on front pillars to reduce mechanical wear, and extensive water cooling had cut down maintenance repair on the front lining to one complete renewal during one campaign.



Previous small access wicket in regenerator.

Other factors contributing to increased campaign life were: a B.R.I. gun, used for maintenance inside the furnace; checker blowing, which appeared to result in loss of air preheat temperature, taking a day or two to regain, but which made it possible to raise the bearer arches by a foot, which, in turn, had speeded up removal of the flue dust on rebuilding.

Except in extreme necessity, top repairs were not carried out at East Moors. There were two categories of general repair. The first included roof, linings and walls, uptakes, and pulling slag and top courses of checker work, which took seven days from fuel-off to lighting warming gas pipes. The second was similar but added complete checkers: this took nine days from fuel-off to lighting warming gas pipes.

There were 65 bricklayers and 85 helpers in the shop, of whom five masons and 20 helpers were on daywork, rebrickling steel ladles, doors, chutes, etc. Allowing for sickness and holidays, there remained 18-20 masons and 20-22 helpers per shift for 19 shifts during the week. The works labouring force was called upon for all preparatory work, such as cutting down and general brick and slag removal. A weekly incentive bonus was paid to all masons and helpers, based on the weekly production hours of all furnaces. On one general repair, not including work on checkers or uptakes, 1,113 mason-hours, 1,430 helper-hours and 3,161 navy-hours were booked, fuel-off to gas pipes lit being 4 days, 8 hours and 15 minutes. Of the 3,161 navy-hours in this instance, 1,877 (59%) had been spent in the slag pockets.

This emphasised the importance of speed in pulling off slag and preparing the slag pocket area for the bricklayers. This applied especially to fixed furnaces, as on the tilters shields could be inserted between the main body and the intermediate ports, and gas pipes lit without detriment to men working below. To assist in this and other preparatory work, mechanical aids were used wherever possible.

Roofs were dropped by crane, and the charger knocked in the front wall. The debris was thrown on to the valve house floor (on tilting furnaces through the slag notches) whence it was removed by tractor shovels and wagons or dumper cars for removal and sorting. Slag and debris from the slag pockets was removed by tractor shovels, for the access of which the slag pockets had been enlarged. Similarly, regenerator wickets had been enlarged to allow the jib of a mobile crane to enter



Tractor shovel removing rubble and blasted slag from slag pocket.

with buckets for removing the old bricks, and with a pallet for rebuilding. Cardox explosives were used for breaking up large lumps of slag, and a method using sand floor and walls plus stopper sleeves had been adopted for easier placing of the charges.

Once the bricklayers could get on the job it was, said Mr. Williams, very important to ensure an ample supply of easily accessible material, as much for reasons of morale as practical efficiency. Unlike the previous speaker, he had not found that palletising offered particular difficulties. All bricks were unloaded on to pallets in the valve house and taken by fork-lift trucks to the appropriate storage bay, whence they were removed by the same means to positions beneath the hatches in the charging floor and conveyed by crane to the site. Palletised roof bricks were positioned on stands set in front of the furnace, or on the main cross girders of the furnace superstructure. Lining bricks were moved by roller conveyors into the furnace. Quite apart from the advantages of service to the bricklayers, palletising very substantially reduced breakages and chipping. In a further effort to decrease down-time, a brick elevator was now being used for conveying bricks speedily from valve house floor level to positions unattainable by fork trucks, such as regenerator chamber arches. It was also used for delivery of bricks direct to a furnace through the slag notches.

Finally, the speaker said that in initial warming up with coke-oven- or blast-furnace-gas pipes, the roof temperature was raised to 400°C. within 12 hours. Liquid fuel was then introduced and the furnace gradually warmed to top heat 24 hours later. Pipes-on to commencement of first charge was 40 hours.

Joint Discussion

In the discussion following these two papers, Mr. R. A. M. WRIGHT (Stewarts & Lloyds, Ltd.) gave particulars of some repair times at Corby. An ordinary general repair took 3 days 17½ hours tar-off to coke-oven-gas flares in bath. This included new roof ramps, front wall and checkers; repair of doghouses, monkey and wingwalls, and jack arches; cleaning out of runners, flues and slag pockets; and cutting out and relining of taphole.

Another general repair, including in addition rebrickling and ramming in a new bottom, rebuilding one chamber arch and relining air uptakes and bulkheads,



Brick conveyor to top of regenerator arch.

was completed in 7 days 8½ hours. A third, like the second but including both chamber arches, took 6 days 20½ hours.

The methods used to achieve these times included the accurate assessment of labour and materials required, based on records and inspection; palletising and strategic placing of bricks; rapid cooling as soon as the taphole was dried up; dropping the roof by crane slings; use of light-alloy roof centres; discharge of debris (while roof bricks were being laid) through a hole in the stage direct into trucks at valve pit floor level.

For easy slag removal, dry ramps had been built in the slag pockets, covered over with 2-in. bars and insulated with old bricks and sand. A 30 ft. × 10 in. square bloom inserted across a fulcrum made it possible to prise up and remove the slag, so that the slag pockets could be cleaned out in about 12 hours. Basic ends had led to a more friable slag. Checkers had been changed to 13½ × 6 × 3 (10½ in. flues), giving at least 18 months service and easy cleaning.

Mr. Wright gave some further constructional details, including a method of avoiding failure at the doghouse by the use of plastic magnesite and water cooling. Failure in regenerator and slag pocket arches had been minimised by the use of 40/42 Al₂O₃ firebricks.

Shop layout in relation to furnace availability was touched on by several speakers in the remainder of the discussion. Mr. A. W. EVANS suggested that there were marked advantages in a stage railway and ground charger system, as opposed to overhead chargers. With ground chargers it was possible to use overhead cranes without interfering with charging, and when one furnace was under repair the area round it could be made independent of the rest of the shop, so that the part of the railway track serving that furnace could be used entirely for brick movement. Mr. PLUCK agreed. A stage railway with loop lines to serve three or four furnaces was of great value. A furnace under repair could be made quite independent of production operations, and bricks and other material could be stacked on site.

Selection of refractories and furnace design were also commented on. In this connection Mr. Pluck stated that from a single uptake furnace at his works they were gaining information which promised improvements in roof life, and might lead to quicker repairs than with other types of furnace.

Practice in Germany

In the afternoon session Dr. T. P. Colclough welcomed Dr. A. MUND who presented a paper by himself and Dr.-Ing. G. Kreutzer. This paper reviewed the open-hearth process in Western Germany, where it accounted for 52.5% of the steel output. Little reference was made to the various types of repairs or to the value of machinery, which the age and layout of most German works made it impossible to use. It had therefore been necessary instead to develop the highest possible durability of the furnaces and thus reduce the number and duration of repairs. In this way, a degree of utilisation, at least as high as in America, and sometimes even higher, could be achieved.

After discussing furnace design, firing arrangements and the construction of checker chambers and flues, Dr. Mund turned to roof life and said that all-basic furnaces and furnaces with supported or suspended roofs now accounted for 30% of the total, and this proportion was growing.

It included coke-oven-gas, mixed-gas and tilting furnaces, and extraordinarily long roof lives had been achieved. In one large coke-oven-gas furnace with additional oil firing, the roof lasted approximately 1,750 heats, in which the furnace produced 192,000 tons of steel. In another case, with a coal-dust carburetted 60-ton coke-oven-gas furnace, more than 100,000 tons of steel were produced with one roof lining. At the end of December, 1952, the roof of a 35-ton coke-oven-gas furnace reached a life of 4,000 heats.

The so-called box type of roof construction was giving good results. "In this design," said Dr. Mund, "single courses between the lateral ribs are sub-divided, by the insertion of longitudinal ribs, into any desired number of 'boxes.' This provides a further bracing of the whole roof and enables any single prematurely worn places to be secured by filling up the affected boxes with filler bricks."

On the use of oxygen, the speaker said that economic success had been achieved in the enrichment of air to 23% in gas producers; in speeding up scrap melting by enrichment of combustion air to 23-24%; in decarburising by lance in certain cases, such as the production of very low carbon steels; and in desiliconising stahleisen by oxygen injection in the ladle.

Practice in the United States

MR. I. S. SCOTT-MAXWELL (Steel Company of Wales, Ltd.), a member of the Productivity team, introduced the paper by Mr. R. W. Evans and himself. He drew attention to the statistics for basic open-hearth steel-making for 1950 given in the Productivity Report.

There were several differences between the two countries which affected furnace repairs. In the much larger American steelworks, large concentrations of labour could be brought to bear and there was more space available in and around the plant for mechanical aids to quick repairs. Furnaces were larger, averaging 130 tons tapping capacity compared with 90 tons in the U.K., and 75% of American open-hearths were fixed, operating on the hot metal process.

The number of taps per week did not differ materially from British practice, but because of the greater tonnage tapped, and the higher availability of the furnaces, the productivity per unit of plant averaged 57% greater than in Britain. Much of this was due to very high furnace availability in American melting shops, the

TABLE II.—NATIONAL STATISTICS FOR BASIC OPEN-HEARTH STEELMAKING, 1950.

	U.S. (tons)	U.K. (tons)	Ratio U.S./U.K.
Effective Capacity* (Average, 1950):			
Per Year	78,550,000	13,830,000	5.7
Per Week	1,510,000	266,000	
Furnaces:			
Total Number	908	330	2.75
Effective Number	828	265	3.13
Output (1950)	76,500,000	12,890,000	5.9
Output (Average per Week)	1,472,000	248,000	
Furnace-Week Productivity (Output per Furnace-Week)	1,780	937	1.9
Availability†	91%	80%	
Utilisation‡	97.5%	93%	

* Effective Capacity is the output expected in period given normal operating conditions of raw materials, fuel and maintenance. This will be less than the theoretical capacity.

† Availability is the average proportion of the theoretical capacity operable during the period.

‡ Utilisation is the output during the period divided by the effective capacity (i.e., 100% indicates that nothing occurred to upset supplies and maintenance).

TABLE III.—AVERAGE REPAIR FIGURES FOR TWO SHOPS OF A CHICAGO WORKS FOR ONE YEAR.

	No. 2 Shop (14 furnaces at 110 tons net)	No. 4 Shop (14 furnaces at 200 tons net)
Heats to First Patch	133	107
Heats between Patches	73	59
Total Heats on Roof	419	405
Area Replaced by Patching (sq. ft.) ..	1,402	1,927
Percentage of Original Roof Replaced by Patching	187	153
Number of Patches per Campaign ..	4.5	6.1

national average being 91%, while some works attained 96-97% year in and year out. Such results meant that any one furnace was only off production for a total of about two weeks in a full year. The average availability of the three shops at Sparrow's Point was 97.5% or 50.7 weeks out of 52. Part of the reason for the low British figure was the practice of having a "spare" furnace, not normally manned, on which repairs were carried out at a slower pace.

The Americans had the advantage of rich natural fuels and consistent raw materials. In matters of design, a continuous effort was made to attain higher production from existing plants. For example, larger uptakes reduced gas velocities despite higher volumes due to hard driving. By the introduction of wider-aperture checkers and larger-volume slag pockets, checker lives could now be measured in years rather than months.

Roof life was "no longer a headache" to American steelmakers, because roof patching had been brought to a fine art. A length of crown, 50 ft. long by 3 ft. wide could be replaced in four hours. Heat input was not limited nor charging carried out carefully for the sake of roof life. The attitude of the steelmaker could be expressed: "O.K., so I burned her down in a month, but, oh boy, did she tick! Now get cracking." The additional output achieved by hard driving more than offset the increased use of refractories.

Co-operative planning between production staff and the mason's department, and between the mason's department and the other trades and crafts such as fitters, riggers and electricians, was the secret of success. The unifying force was a real desire by everyone to keep all the furnaces working for the maximum number of hours in the year. The production men were just as interested in the repair as those men actually doing the work.

"The urgency of this situation," said Mr. Scott-Maxwell, "has now become so completely inbred in the repair teams in the United States, that during a repair they appear to work with the same sense of desperation as a second hand who is trying to open his taphole to save a charge which is starting to break out through the bottom."

Some of the steps that could be taken in Britain to improve furnace availability were:

- all shops to work more than 19 shifts per week, if possible 21 shifts;
- the idea of "spare" furnaces should be forgotten and all such furnaces manned when raw materials are available;
- quick patching technique of roof repairs to be adopted together with higher operating temperatures;
- better scrap preparation;
- development of mechanical aids to quicker repairs suitable to British melting shops, such as light-alloy roof centres, hanging platforms, brick elevators, palletisation, etc.;
- quicker methods of slag removal; and
- heavier furnace steelwork, additional water cooling, quicker methods of wrecking the furnace.

In the U.S.A. a top repair, including complete roof, front and back linings, uptakes and blocks could be carried out in 21 hours, fuel-off to fuel-on. Such fast repairs were achieved by concentrating a large labour force on the job and ensuring a high degree of detailed planning before the work began.

At Sparrow's Point, for example, a tentative schedule was made for six months and each of the 28 furnaces appeared twice, either for a general or a quick top repair. A general repair took about four days and a quick roof repair about 25 hours. Such repair times could only be achieved after long practice and the development of time-saving mechanical aids which fitted into the normal working of the shop.

A typical manning in an American hot metal shop with 12 furnaces of 180 tons capacity would be approximately:

	Total Men per Day	Men per Furnace per Shift
Masons	70	1.7
Masons' Labourers ..	75	1.8
Wreckers	68	1.9

The speaker described the organisation of typical furnace wrecking and rebuilding operations. When the repair was completed, furnaces were brought up to temperature relatively quickly. After a general repair, charging would begin about 15 hours after first lighting up and the first tap some 27 hours after.

At the Lachawanna plant of Bethlehem Steel Corporation, by paying close attention to heating-up rates, the time to tap after repairs had been reduced to an average for a year, of 22 hours, with an occasion when 16½ hours was achieved. Initial warming up was started as soon as top repairs were complete, and before bottom repairs were finished. Up to 600° F. great care was taken.

Discussion

In the ensuing discussion, Mr. G. R. BASHFORTH (Round Oak Steel Works, Ltd.) referred to the effect on availability of the layout of old plant. At his works, in the old melting shop with two 90-ton tilting and five 60-ton fixed furnaces, an availability of 81.2% had been achieved. In their new plant they had some early troubles (which the speaker described) during the first two years of operation, but the schedule for 1952/3 aimed at an average furnace availability of 91.8%, with eight general repairs of 11 days and six top repairs (not including regenerators) of nine days. Although the adoption of the new schedule and improved methods was recent, so far out of 11,520 furnace-hours available, they had operated 10,416 furnace-hours—90.4%.

Mr. R. WOGIN (Appleby-Frodingham Steel Company) commented that the difference between oil-fired and gas-fired furnaces was a fundamental reason why British repair methods and results must always fall short of American. He thought that where a British gas-fired furnace had a 10-day repair, compared with four days, the best at Sparrow's Point, four days of the difference lay in the design of the furnace. There was 25% to 50% extra brickwork to cool down, a 4 ft. to 5 ft. wall separating the air from the gas system and two slag pockets instead of only one.

Even so, the latest 300-ton furnace general repair at the speaker's works, including ramming in a bottom,

taking 140 tons of slag out of the slag pockets, replacing air checkers to ground level, and redesigning the block, was completed in five days one hour from gas-off to beginning to warm up. Sixteen men per shift wrecked the furnace and eight bricklayers per shift rebuilt it.

Mr. A. PROVIS (Guest Keen Baldwins Iron and Steel Co., Ltd.) spoke as one who had worked as a furnaceman and mason's helper in America. He said that co-ordination was materially assisted by the equivalent status of the shop superintendent and superintendent of masons.

"No mere lip service is paid to schedules," he said, "they are attained or, if they are not, somebody is blamed for it, and this control works down the line to the individual chargehand actually on the job, who is given a particular amount of work to do in a particular eight-hour shift. The American foreman and chargehand is educated to a sense of responsibility, is willing to accept it, and is paid to do so."

Additional factors he had found to contribute to increased furnace availability figures were:

- (1) the use of basic bricks with particular reference to zebra roofs;

- (2) the use of super-duty silica bricks;
- (3) spray guns handled by first helpers for inside furnace maintenance in such areas as the taphole and both skewbacks, and by masons for plugging holes in slag pockets and the regenerator chamber;
- (4) emphasis on efficient checker cleaning and the installation of soot blowers under the bearer arches and along the flues;
- (5) a continuous flow of materials to the site when a repair job was in progress and a minimum amount of piping, beams, bars and any steelwork to impede men's work.

Mr. Provis thought that production men at the conference had to see that the efforts of the engineers were backed up "by regarding minutes saved now as more valuable than hours later on; by the education of the labour force to a sense of urgency; and by a tendency towards a slight over-manning of maintenance forces. Perhaps a 1% overman might be more economic than a 0.25% underman when related to greater availability and, therefore, productivity figures."

North Eastern Foundrymen Visit Clarke Chapman's Works

ABOUT 100 members of the Newcastle Branch of the Institute of British Foundrymen accepted the kind invitation of the management of Clarke, Chapman & Co., Ltd., to visit their foundries on a recent Saturday morning. In addition to opening their foundries considerable enthusiasm was shown by the staff in discussing their problems and in explaining how they were being overcome, and, at the conclusion of the visit, a very substantial lunch was provided for the members.

This firm was founded in 1864 by Mr. William Clarke with the object of manufacturing marine auxiliary machinery. In 1874 the works were removed to the present site in Gateshead and during that year Mr. Clarke was joined by Capt. Chapman, the firm continuing to develop in the manufacture of marine machinery, particularly ship's deck machinery. In 1884 the then Hon. Charles A. Parsons entered the Company and remained with it for five years, during which time he developed his turbine, eventually forming his own Company in 1889. During this latter period, Clarke, Chapman's began to manufacture electrical gear, which still forms a large part of the firm's activities. In addition, however, the firm now makes boilers, colliery haulage machinery, conveyors, pumps, pulverised fuel plants, ship's lighting equipment and large reflectors.

Although this firm is long established, and in consequence many of its buildings are relatively old, manufacturing practices are in line with modern practice, indeed, the modern metallurgical and chemical laboratories, which form part of these works would grace a much larger works. The foundries, which cover an area of 41,310 sq. ft., produce all grades of iron castings to B.S. specifications, including austenitic irons, Nicrosilal, low nickel and chromium irons, and alloy irons containing molybdenum and vanadium. The tonnage of metal produced is considerable, one year reaching 13,884 tons, and when it is realised that the floor area used per annual ton of metal is 5.75 sq. ft. in comparison with 9 sq. ft. in the United States it will be appreciated that output is of a high order.

The ferrous foundry is equipped with two cupolas, 48 in. and 30 in. in diameter, respectively; a 1-ton capacity rotary furnace, and a 1-ton capacity surface-blown converter. The melting plant in the non-ferrous foundry comprises several 200 lb. capacity pot furnaces and two larger tilting furnaces.

It is not surprising that the visit proved both interesting and informative, and there can be no doubt that the members of the firm's staff, as well as the visitors, profited from the discussions which took place in the various sections of the works visited. The President of the Newcastle Branch expressed hearty thanks, on behalf of the members and himself, for the courtesy and hospitality extended to them, and for the excellent manner in which the visit had been organised.

Magnesium Elektron, Ltd., at the International Magnesium Exposition

At the International Magnesium Exposition to be held in Washington from March 31st to April 2nd, and which has been organised by the Magnesium Association, New York, Magnesium Elektron, Ltd., will be represented together with virtually all their Licensees, both British and foreign, on a large stand covering 1,400 sq. ft. Not since 1937 (in Berlin) has so comprehensive a display of magnesium cast and wrought products been on view. This will also be the first occasion on which the individual members of the Elektron group will provide a collective display.

Future of the B.I.F.

RUMOURS that this year's British Industries' Fair is to be the last are without foundation, and immediately the Coronation Fair is over work will begin on the 1954 Fair, which is to be held in London and Birmingham. The Exhibitions Advisory Committee is studying the long term question of the best way to organise the Fair, but it has already informed the President of the Board of Trade of its unanimous opinion that the Fair should continue.

Modern Electrical Controls in a Continuous Aluminium Strip Mill*

By P. E. Peck, B.Sc., A.M.I.E.E.

(Industrial Engineering Department, The British Thomson-Houston Co., Ltd., Rugby.)

The continuous aluminium strip mill at Rogerstone contains examples of nearly all the modern processes used in the treatment of strip metal. In this article some of the problems involved in controlling the drives for the mills and auxiliary lines are discussed.

MUCH has already been published† about the continuous aluminium strip mill at the Rogerstone Works of the Northern Aluminium Company, which was completed towards the end of 1950. In this article, therefore, it is proposed to give only a brief description of the mill, as a background to the consideration of some of the problems involved in controlling the electric drives.

The ingot for rolling, either imported from Canada or cast in the remelt department, is first scalped to remove surface roughness. After pre-heating, it is passed down the hot line for successive hot rolling through two independent reversing mills, followed by two hot-finishing mills operated in tandem, being end-sheared and side-trimmed in process before being coiled at the end of the line. After cooling, the coil is transferred to the cold-rolling mill, where it is passed through a three-stand tandem cold mill. Subsequent treatment depends on the use for which the sheet is required. Coil intended for building sheet is passed to the heavy shear line where it is flattened, cut to length and corrugated if required. Coil for any other purpose passes on to a slitter, where it is edge trimmed or slit into strips. If intended for circles for hollowware, it goes to the circle mill where the discs are cut on a blanking press. Other material is put through the annealing furnace. After annealing, foil stock is in the condition required by the customer, but container sheet is rolled to the required hardness in a temper mill before being delivered to a continuous-type light shear line for degreasing, edge-trimming, checking for gauge and quality, cutting to length and, finally, sorting.

From all these processes it is proposed to refer to some of the problems involved in hot and cold rolling, and in the control of the slitting and shear lines.

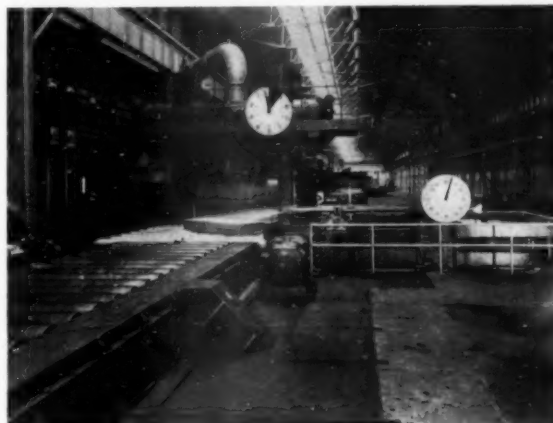


Fig. 2.—View of the No. 1 hot mill showing a slab on the turntable.

Hot Rolling

In the hot line, whose layout is shown in Fig. 1, 9 in. thick slabs are rolled down to a thickness of 0.1 in. without intermediate reheating. The slabs, which have already had surface blemishes removed in a scalping machine, are heated in continuous push-through type furnaces, and deposited by a crane-type discharger on to the ingoing roller tables of the first reversing hot mill. This mill has a 35 in. diameter \times 96 in. wide rolls, and the roller tables on each side of the mill are synchronised with the mill control to reduce to a minimum the possible scratching of the strip. On the entry side of the mill, there is a turntable which permits the slab to be turned sideways for broadside rolling in order to increase its width to that required for the final strip, after which it is turned lengthwise again for all further rolling.

After breaking down in the No. 1 mill (Fig. 2), the

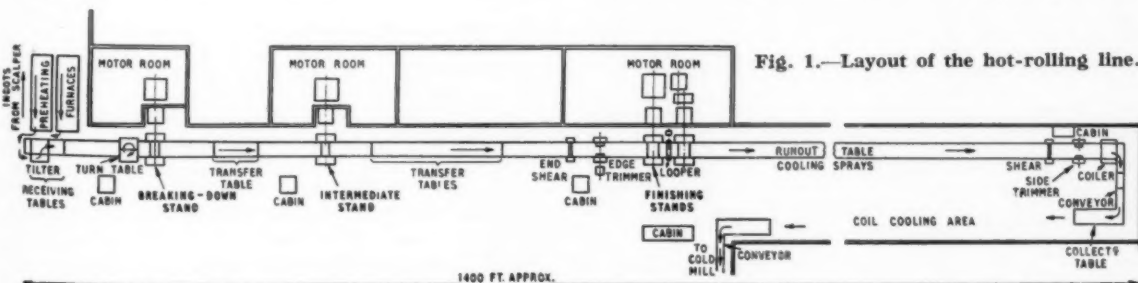


Fig. 1.—Layout of the hot-rolling line.

* Informal paper read before the Institution of Electrical Engineers, Rugby Sub-Centre at Banbury.

† For a general detailed description of the plant, see *Metallurgia*, 1950, October, 42, 223-232.

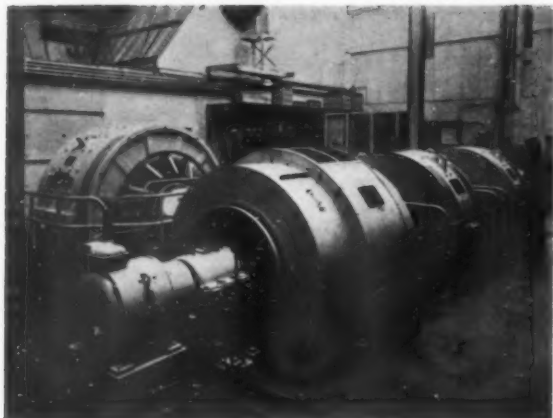


Fig. 3.—Main drive motor and motor generator set for No. 1 hot mill.

material is transferred along the roller table for further rolling in a second reversing hot mill, the No. 2 mill, from which it passes to a 2-stand tandem hot-finishing mill, along a run-out table with cooling sprays, to a hot-strip coiler, being sheared and trimmed on the way.

The drives for the reversing mills are shown in Figs. 3 and 4. The 2,000 h.p., 40/51 r.p.m. reversing motor for No. 1 mill can be seen in Fig. 3 together with its synchronously-driven motor generator set. An interesting feature of the drive for No. 2 mill, seen in Fig. 4, is the fact that the 1,625 h.p., 40/51 r.p.m. motor is supplied from two separate flywheel motor generator sets. This unusual arrangement is due to the fact that this mill was originally a hot breaking-down mill, and it was found that longer passes were possible without overheating the motor. A second set was, therefore, added to give the additional flywheel capacity to take advantage of this position.

Reversing Hot Mill Controls

The chief problem in the control of a reversing hot mill is that of making the fields of the generators and motors change sufficiently quickly to give the required rate of acceleration, retardation and reversal. This is

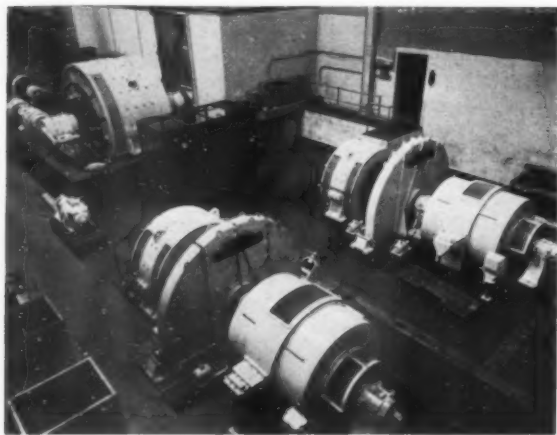


Fig. 4.—No. 2 hot mill main drive motor and its two flywheel motor generator sets.

due to the high inductance of the field winding and its linked circuits, and what is known as field forcing is used to overcome this difficulty.

Fig. 5 shows how this is effected in this particular case. It will be seen that the generator exciter which supplies the generator field has two field windings, one of which is fed from (and under the control of) the master controller, with something like three or four times the required ampere turns to maintain the final generator voltage. This causes the generator field to increase very rapidly, but it is finally checked and maintained at the required value by an opposing differential field, which is connected across the generator and excited proportionally to the generator voltage. This is a simple and effective scheme and gives quite good reversal times.

Turning to the control of the motor field, a similar principle is used, but in this case the forcing is obtained directly by a differential series winding on the motor exciter carrying the actual field current. The machines for these mills have quite a short speed range on field control (40/51 r.p.m.) and two steps of field weakening are considered adequate.

The diagram also shows the means used for matching the speed of the tables to that of the mill. This cannot be done by a straightforward voltage control, as increase of the mill speed by field weakening does not involve any change of the generator voltage. The speed of the tables is, therefore, arranged to be equal to that of the mill at full speed, when the table motors have reached the full mill voltage. At speeds less than full speed, the

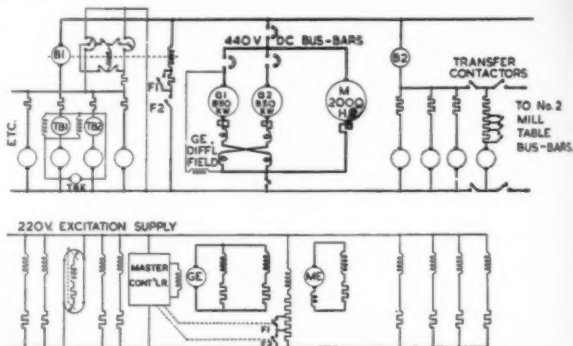


Fig. 5.—Diagram of reversing hot mill controls.

speed of the tables is reduced by means of two table boosters which have one field arranged to provide a voltage dependent upon the excitation of the mill motor, yet at the same time proportional to generator voltage, so that as the generator voltage grows the bucking voltage also grows. A second field on the booster is connected through reversing contactors to draft compensation rheostats, so that the speed of the tables on the ingoing side of the mill is reduced and that on the outgoing side of the mill slightly increased to compensate for the change in speed of the material due to the draft of the mill. These rheostats also provide compensation for roll-diameter variations.

One further detail to be considered is the control of the turntable. The two halves of the table are separately driven and their motors fed through separate boosters. For normal operation, these boosters are suicided and the tables run in synchronism with the other mill tables.

Operation of the turning rheostat in the pulpit, however, excites the boosters in opposite directions, with the result that at one side the rollers are speeded up and at the other side slowed down. (Alternatively, if the mill is at rest, the two sides rotate in opposite directions and this causes the slab to rotate.)

When rolling is completed, the slab continues to the transfer table and changeover contactors switch the feed of this motor to the table-motor circuits for the following mill. Accelerating contactors in series with the transfer-table motor enable this to be done on the "fly." This transfer is brought about by means of control switches in the mill-pulpit desks, which also permit various other sections of table to be cut in or out at the will of the operator.



Fig. 6.—Tandem hot-finishing mill and its 700 ft. run-out table.

Two-Stand Tandem Hot Mill

After rolling in No. 2 mill, the strip proceeds to two stands in series, in each of which it receives a single reduction and emerges in its final hot-rolled state to proceed along the 700-ft. run-out table (seen in Fig. 6) to the coiler.

The main requirement of a hot-finishing mill of this sort (Fig. 7), is that the speed of the stands should be maintained within reasonably close limits to avoid breaking the material due to pulling, on the one hand, and to prevent the formation of a loop between the stands, on the other. Such loops as are formed when setting up the mill are taken up and held steady by means of the looper roll until the speed of the outgoing stand can be corrected.

The first stand is driven directly by a 3,000 h.p., 48/96 r.p.m., D.C. motor (Fig. 8), and the second stand by a 2,600 h.p., 200/400 r.p.m., motor which drives through a 1:57:1 reducing gear. Provision has been made for the addition of a preceding and succeeding stand to this section of the mill at a later date, and this section of the plant is very similar to that adopted in the most modern plants for rolling hot steel strip.

Tandem Cold Mill

Coils from the hot-strip mill, after cooling, are taken to a three-stand tandem cold mill (Fig. 9) for cold rolling. This is a 66 in. wide mill with a maximum



Fig. 7.—Close-up view of the tandem hot-finishing mill, showing the looper roll between the stands.

output speed of 2,100 ft./min., the finished material being coiled on a tension reel which can take coils up to 4,000 lb. in weight, Fig. 10.

Each stand is separately driven by a 2,600 h.p. double-unit motor, the first stand being driven through a reduction gear and the other two stands direct. The reel is driven by two duplicate 400 h.p., 400/1,000 r.p.m. motors.

Tandem Mill Control Scheme—Main Circuits

Fig. 11 shows the basic arrangements and main circuit of the mill, but before discussing the details some of the problems involved in the cold rolling of strip will be considered. The gauge of the outgoing strip may be as low as 0.01 in., and it is obvious, therefore, that very small inaccuracies will have a relatively large effect upon this thickness. During the process of rolling, the strip is being reduced in three separate stands, and the speed relationship between these stands must be maintained within very close limits. The strip is rolled with tension between stands, and any variation of this tension will result in a difference in the reduction in the strip, even if the settings of the rolls are not altered. This also applies to the tension maintained in the outgoing strip by the tension reel, which is further complicated

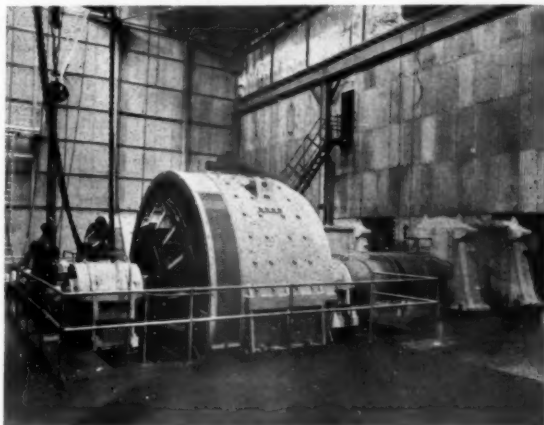


Fig. 8.—Hot-finishing mill motors.



Fig. 9.—Tandem cold mill.

by the fact that as the coil builds up the speed of the reel has to decrease to maintain constant linear speed of strip. On top of all this the mill has to be accelerated from the speed at which the material is threaded through it, up to the required rolling speed and finally retarded again as the end of the strip passes out to the reel. This means that during acceleration and retardation, in addition to the torque required to reduce the metal between the rolls and maintain the tension between the stands, more or less torque is required to compensate for the inertia of the moving parts. Thus, during acceleration and retardation there are two effects tending to make the strip go off gauge, one due to the change in the speed of rolling and the other due to these inertia forces tending to unbalance the tension between stands. The tension exerted by the reel is also affected by the inertia of the reel motors and the coil itself.

The main circuits for the mill are shown in the bottom half of the diagram, and it will be seen that all the machines are fed from common busbars supplied by three generators in parallel, the latter incidentally being driven by a 10,000 h.p. synchronous motor. It will be noted that in series with each mill motor and each reel motor is a series booster, and it is through these machines that the various special control features are introduced.



Fig. 10.—Output side of tandem cold mill showing tension reel.

The whole mill is accelerated and retarded by variation of the generator voltage by means of a master rheostat controlling the fields through a regulating exciter Amplidyne and a main generator exciter.

Tandem Mill Control Scheme—Stand Controls

Turning now to the control for a single stand, Fig. 12, the diagram shows in a simplified form how the various controls are introduced.

The coarse setting of the motor field is adjusted by means of a motor-operated rheostat, and fine adjustment is provided through a small buck boost exciter from a rheostat mounted in one of the mill-stand cabinets. This exciter is differentially connected to ensure quick response, and its presence as an amplifier enables a small enough rheostat to be used for mounting in the control cabinet.

The main series booster is excited by the booster regulating exciter, an Amplidyne-type machine with several field windings through which the different control signals are introduced.

Stabilising and Speed Adjustment.—This field is fed from a stabilising transformer connected across the

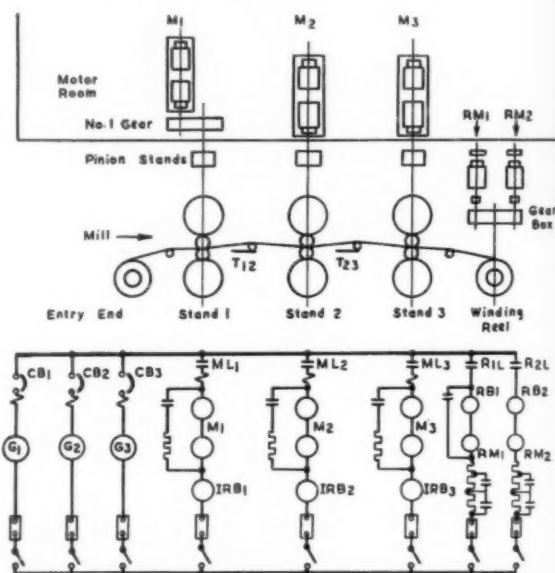


Fig. 11.—Layout and main circuit of tandem cold mill.

regulating-exciter armature, but it is also used for giving momentary speed control to correct quickly the formation of a loop, or the building up of excessive tension while the relative stand speeds are being adjusted by the motor-field controls. This is only provided on the first and last stands, the second stand being regarded as the master.

Inertia Compensation.—This field is fed through a condenser from the voltage across the mill motor and is, therefore, only sensitive to changes in this voltage. During acceleration, when the voltage is rising, the signal is in such a direction as to cause the booster to boost the main generator volts and increase the current flowing through the motor armature. The amount of this signal is governed by a faceplate on the mill-motor coarse rheostat, so that the correct signal is obtained

whether the motor is running up to base speed, full speed, or any intermediate speed.

"IR Drop" Compensation.—This field compares the voltage across the booster with the drop across the mill-motor compole and compensating winding and series field, and is so connected that the booster tends to compensate for the resistance drop through the motor. The amount of this compensation can be adjusted according to whether the mill is to run "hard" or "soft." The IR drop compensation helps to take care of the variation of speed due to a dissimilar current in the

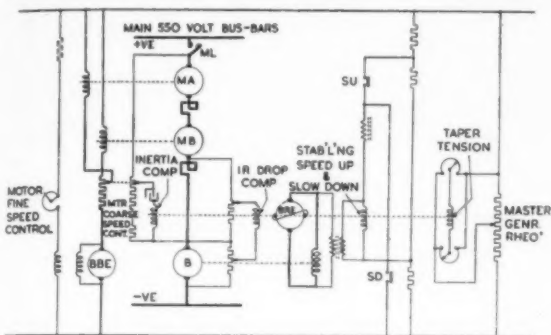


Fig. 12.—Diagram of tandem mill stand control.

various motor armatures, and is particularly important during acceleration and retardation.

Taper Tension.—As already explained, the tension between stands must be decreased as the mill accelerates, and increased as the mill retards, to counteract the tendency for the strip to go off gauge. The control signal to correct for this effect is obtained from a further field on the booster regulating exciter, fed from a faceplate on the main voltage control rheostat and so connected as to tend to slow the No. 1 stand motor down and speed the No. 3 stand motor up, by an amount dependent upon the speed of the mill. The effect is reduced to zero at full voltage on the busbars. Small rheostats on the cabinet enable this effect to be adjusted or cut out altogether.

Tension Reel Control

As already explained, the problem here is to maintain constant tension in the strip as the diameter of the coil increases on the reel mandrel. It will be clear that what is wanted from the reel motor is constant power and not constant torque, because as the strip speed remains constant and the tension remains constant, therefore, the power required remains constant. But the torque required has to rise, and the immediately obvious means of control is to strengthen the motor field in proportion to the increase of diameter of the coil. Fig. 13 shows the reel motor fed from the main busbars and again having in series with its armature a booster, the latter having two fields, one excited by a further Amplidyne, RBBE, the other being excited proportionally to generator volts and the setting of the Stand 3 motor-field rheostat, so that the reel-motor field control has only to deal with coil build-up.

Tension Control.—The current through the reel motor is measured by means of a resistance shunt and amplified by an amplifying generator AG. If the current exceeds a certain value, the voltage of AG exceeds the voltage tapped off from the tension-setting rheostat, and

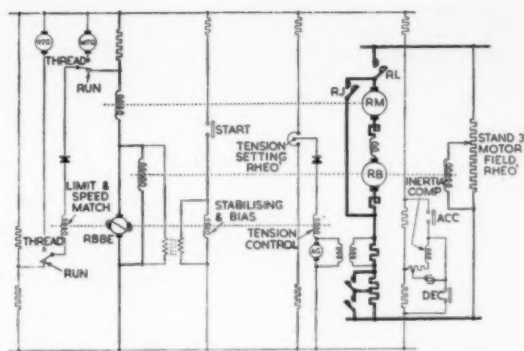


Fig. 13.—Diagram of tandem mill reel control.

current "spills over" through the RBBE field to excite it in such a direction as to strengthen the reel-motor field.

Next to the tension-control field is the bias field, which is energised as soon as the reel is started up, in such a direction as to cause the reel buck boost exciter to tend to weaken the reel-motor field so that, initially, before tension is applied or the strip fed to the reel, the reel motor tends towards the weak field condition. During threading, however, the actual reel-motor speed is held to the required value by the speed-matching field.

Speed-Match and Limit.—With the contacts in the thread position, the speed-matching field compares the voltage between the reel tacho-generator and the motor tacho-generator and if the reel tacho-generator voltage exceeds that of the motor, current flows to strengthen the reel-motor field and slow the reel down; this avoids snatch as the reel takes up the strip. On moving over to run, this field acts purely as a limiting field to prevent the reel-motor field from being reduced below the minimum weak field value.

Inertia Compensation.—To compensate for the extra current required to maintain tension when the reel is accelerating, or the reduced current required to maintain tension when the reel is retarding, the signal to the amplifying generator is modified by a certain amount, according to whether the accelerating or retarding contactor is closed to operate the master rheostat.

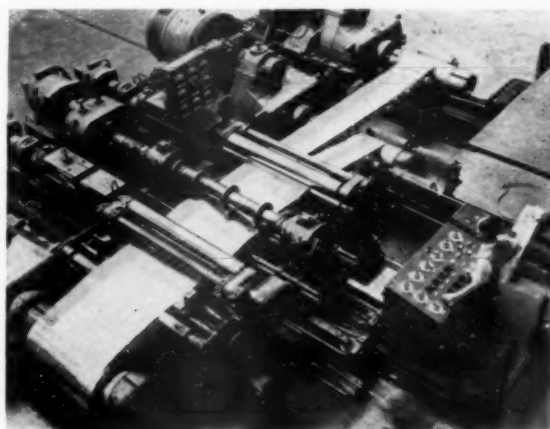


Fig. 14.—Sheet slitting line in operation.

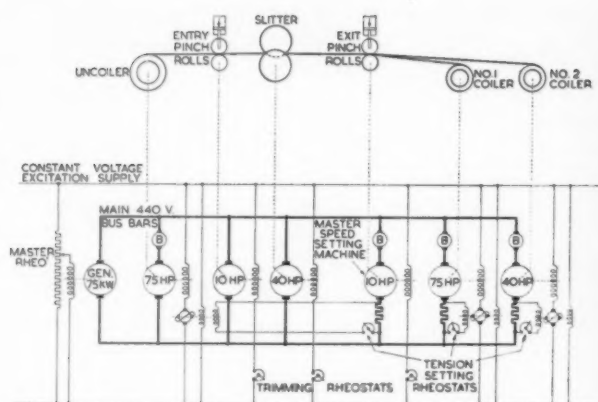


Fig. 15.—Diagram of drive for slitting line.

Inching.—The reel booster is also used for inching the reel motor independently of the mill, in which case the contactor R_J is closed and the field across the reel buck boost exciter disconnected and fed by a suitable voltage.

The effect of this field across the RBBE during reeling is first to control stalled tension and, secondly to change gradually the booster voltage in such a way as to assist the tension control and reduce the range of armature current required to increase the field current from the weak-field to the full-field value.

Slitting Line

The purpose of the slitting line (Fig. 14) is to trim the edges of the strip from the tandem cold mill, slit it into separate widths, and recoil it. The maximum width of strip is 56 in. and the coil from the tandem mill is placed on an uncoiler mandrel, passed through pinch rolls to the slitter, and through further pinch rolls to two separate coiling machines where it is wound on steel formers. One of these coilers can coil up to the full width of the material if it is not required to slit it, or

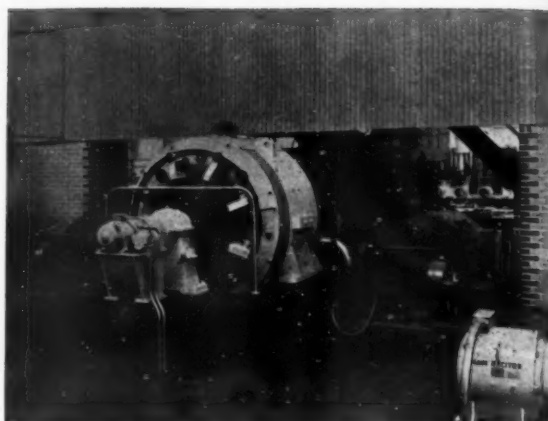


Fig. 18.—Temper mill motor-room.

carry two coils if it is desired to slit the strip into three.

On the face of it, the drive would appear to be fairly simple, but the means of control is worth considering. As can be seen from the diagram, Fig. 15, all the machines are fed from a common generator and their speeds raised or lowered together by voltage control. Constant tension must be maintained on the coilers as the coils build up, and at the same time constant back-tension must be maintained on the uncoiler as the diameter of the coil decreases. Furthermore, the tension on the two coiling machines may be different.

Balancing the coiler tension directly against the uncoiler tension cannot be satisfactorily effected as the slightest inaccuracy would result in the whole line either gradually speeding up or gradually slowing down. The outgoing pinch roll is, therefore, made the master to maintain constant speed. The pinch-roll motor is a separately-excited shunt machine with fixed excitation, and its current is used to regulate the field of the uncoiler motor so as to maintain the pinch-roll-motor current constant. As the two coiler motors have their

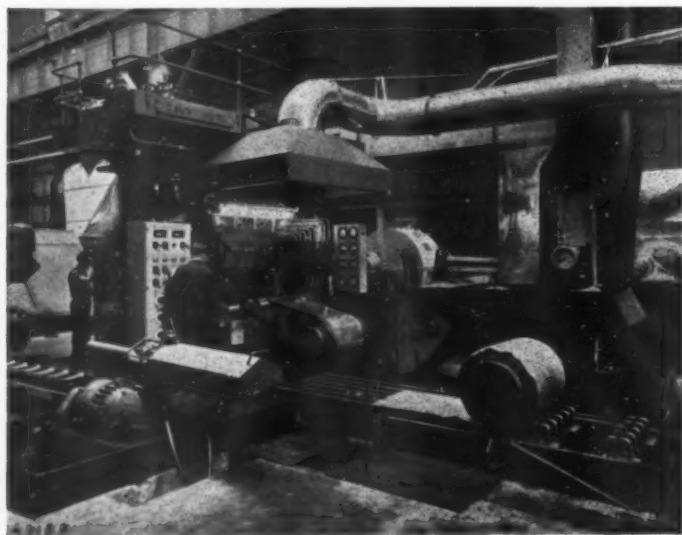


Fig. 16.—Temper mill.

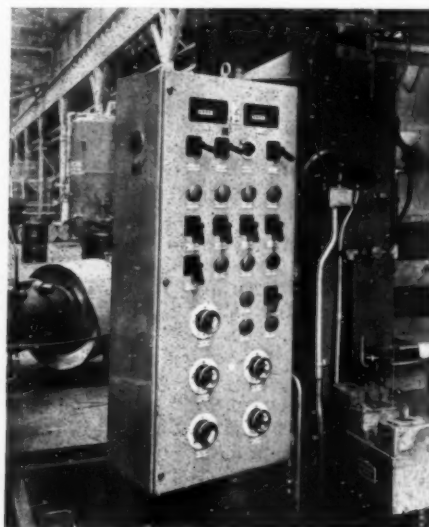


Fig. 17.—Temper mill control cabinet.

own tension control arrangement to maintain their own armature currents constant, this means that the uncoiler machine will always operate to balance the tension of the two coilers, apart from such differences as are introduced by the pinch roll and slitter, which are relatively small.

Cut-Up and Classifier Lines

After leaving the slitting line, the strip is annealed in a furnace and is then subject to temper rolling in a single stand temper mill (Fig. 16), for which the controls are very similar in many respects to those for the tandem mill, except that there is only a single stand, and both the uncoiling and winding reels have tension control, correct front and back tension being a very important factor in temper rolling. Control of the mill is from cabinets mounted on the mill stand, as seen in Fig. 17, the machines being in a motor room (Fig. 18).

After temper rolling, the strip proceeds to the cut-up and classifier line or light shear line, where it is cleaned, cut to length and classified according to gauge. A general view of the line is shown in Fig. 19, and here again there are some interesting control problems of quite a different nature. The diagram, Fig. 20, shows that from an uncoiler the strip passes to a welder, through a washer which removes the oil and grease left from rolling, to a flying shear, and is finally piled after passing over a series of conveyor belts, with deflector gates so that off-gauge material can be piled separately from correct gauge sheets. The welder is used for connecting one coil to the previous one so that material passes continuously through the washer.

To ensure that there is no tension on the ingoing side of the shear, and also to control the speed of the uncoiler motor as the strip unwinds, loops are provided on each side of the washer, the loop of material being arranged to interrupt the light falling on two photo-electric cells which adjust the controls to maintain correct strip speed. The whole line is accelerated from rest and brought to rest by voltage control from a common generator.

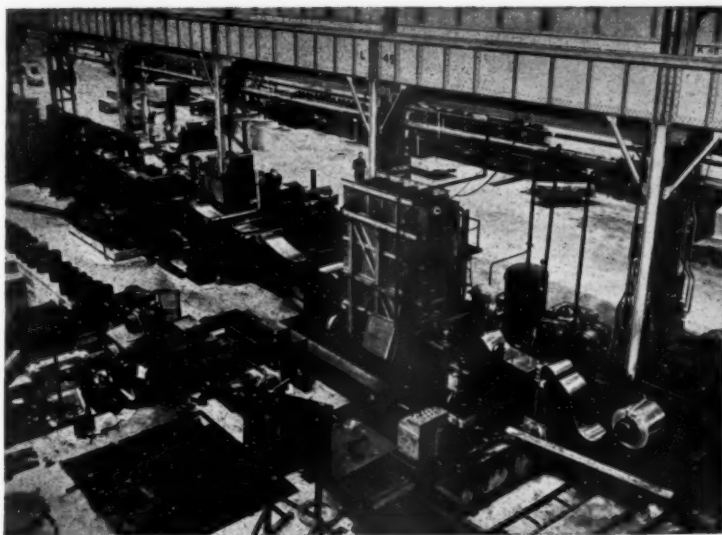


Fig. 19.—Cut-up and classifier line.

The actual loop control is an interesting example of a method which is quite simple in comparison with some of the controls on the tandem mill, for example, and yet is perfectly effective for its purpose. The final diagram, Fig. 21, shows the means adopted for this loop control. If the loop is above the upper dotted line, both photo-cells are energised and the raise-speed contactor will be energised to adjust the rheostat to increase the uncoiler motor speed. An immediate correction is, however, provided during this process by a contact on the raise-speed contactor inserting resistance in the field circuit as long as the rheostat is moving. This results in the loop quickly settling down within the limits.

If the loop is too great, the reverse process takes place, and when both photo-cell beams are interrupted the lower-speed contactor is energised, and simultaneously a portion of the field rheostat is short circuited to provide an immediate correction while the rheostat arm is travelling.

During the unwinding process on the uncoiler, the tendency will be, of course, for the loop to decrease as the diameter of the coil decreases and the control,

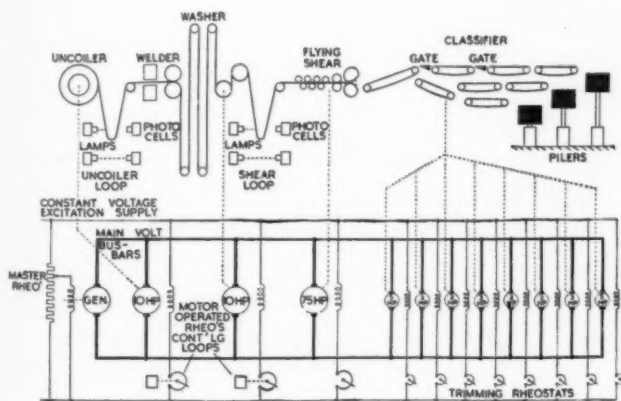


Fig. 20.—Diagram of drive for cut-up line.

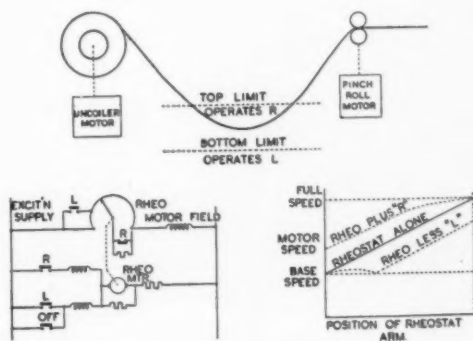


Fig. 21.—Diagram of automatic loop control.

therefore, operates to increase the speed of the coiler motor at regular intervals. The loops also serve to take care of any variations which take place during acceleration.

Conclusion

It will be seen that a very wide variety of problems have to be met in a plant of this magnitude and, furthermore, that the electrical applications engineer has to be familiar not only with the characteristics of electrical

equipment but also with the behaviour of the rolling mills and auxiliary plant in order to provide a satisfactory drive.

In conclusion the author wishes to thank The British Thomson-Houston Co., Ltd., the Northern Aluminium Co., Ltd., and the Institution of Electrical Engineers for permission to publish this paper, and to the colleagues who commissioned the drives for their assistance in its preparation.

Arc Melting for the Foundry New Birlec Installation at Hadfields

DURING the last few years, an extensive programme of reconstruction and modernisation involving an expenditure of £5 million has been in progress at the works of Hadfields, Ltd., and reference has already been made in *METALLURGIA* to the new heavy forge. A further important stage, this time in the foundry development plan, was reached recently with the first pouring of the 20-ton Birlec Lectomelt direct arc melting furnace which is to be used mainly for the production of high quality steel for castings, and which will normally be operated continuously.

The furnace is located between two bays, so that the crane system in one serves the charging operation, whilst that in the other bay handles the pouring ladle. The installation of the furnace involved the erection of a complete melting shop, including two 40-ton electric overhead gantry cranes with 10-ton auxiliary hoists, an 18 ft. 10 in. deep pouring pit, an ingot casting pit, a pit to contain the scrap charging bucket, the necessary house for the transformer, automatic electrode control gear and switchgear, and the electrode winch gear.

The Birlec Lectomelt steel melting furnaces are based on the designs of the American Pittsburgh Lectromelt

Corporation which has long experience of building large arc furnaces. This type of equipment is supplied in Great Britain, the British Empire and many other countries by Birlec, Ltd., who are manufacturers of an extensive range of heat treatment and melting furnaces.

Furnace Body and Roof

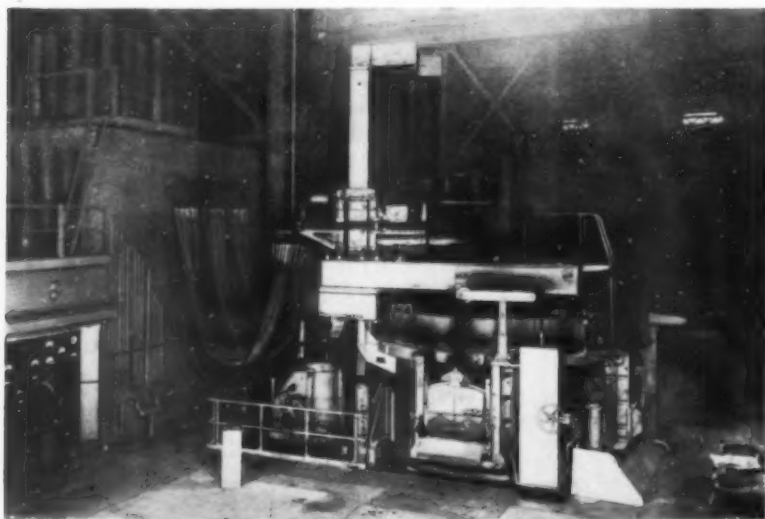
The furnace shell is cylindrical in shape with a dished bottom, and its diameter of approximately 14 ft. and other leading dimensions ensure that the furnace provides a large area of contact between slag and metal. It is constructed of heavy gauge steel plates reinforced with structural steel members and, to prevent distortion of the shell under heat, a heavy top stiffening bezel ring is provided, the ring being water-cooled. The shell is lined with metal-cased magnesite tubes.

Two door openings are provided in the shell, one opposite the pouring spout and the other at right angles to this diameter, opposite the electrode masts. The former door is used for slagging, stage plates being removed to allow the slag to be poured or raked into boxes below stage level, while alloy additions are made through the latter. The door openings are provided with vertically sliding doors, running in accurate guides and operated by push-button pneumatic control.

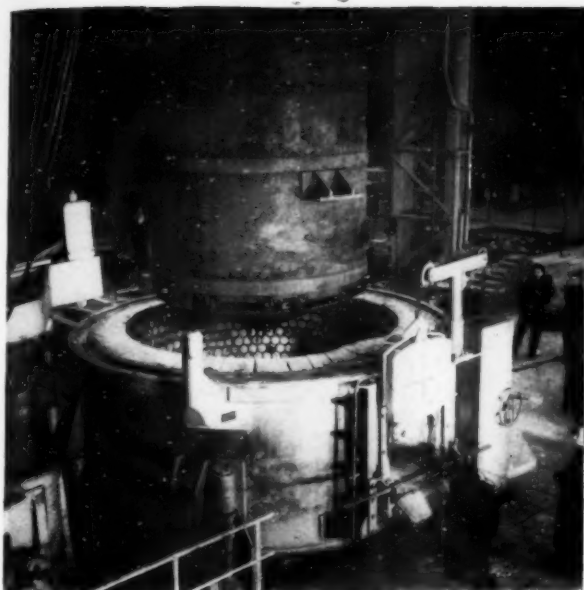
A robust pouring spout is attached to suitable reinforcements on the shell, and as with the doors, it is designed for easy refractory lining.

Two roof rings are provided with the furnace; they are constructed of heavy channel-section steel and are built to a larger diameter than the furnace shell. The life of the skew-back bricks is greatly increased by the fact that this feature removes them from the heat of the molten metal. As a precaution against distortion, the roofing is also water-cooled.

The roof is suspended at four points from two structural beams—an arrangement known as "four point roof suspension" which, in this installation, is incorporated for the first time on a 20-ton arc furnace. Roof change is greatly facilitated as

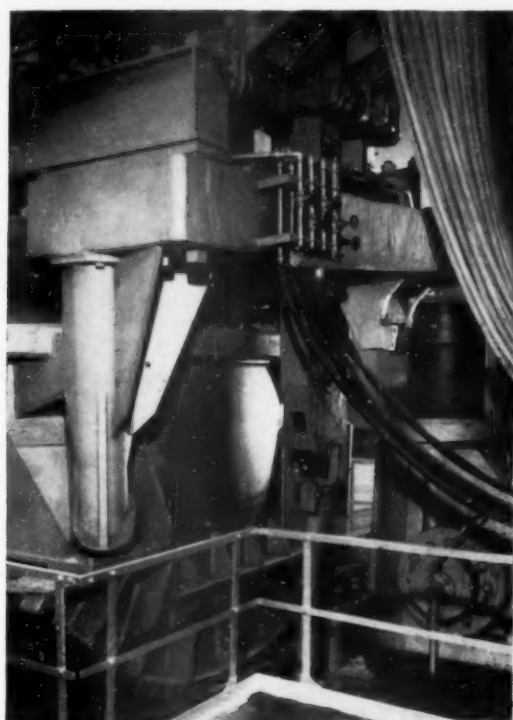


General arrangement of the installation with transformer house and control panel on left.



The shell interior is lined with metal-cased magnesite bricks.

The lifting ram mounted at the rear of the furnace; the heavy eye casting can be seen with the parallel roof beams attached; one of the tilting rockers is also shown.



the replaced roof can be quickly removed, by unfastening the four holding screws, and the new one is easily located in the correct position so that no trouble arises with the alignment of the electrodes with the electrode ports.

Roof Lifting and Tilting Mechanism

The most notable design feature on this furnace is the lift and swing aside roof which enables the complete hearth to be exposed for charging or fettling. The complete furnace roof structure, suspended from the two parallel beams, is secured in a massive eye-casting which weighs over 10 tons. A vertical hydraulic ram engages this eye and lifts the roof clear of the shell. The teeth on a horizontal hydraulic ram mesh with teeth on the vertical ram so that lateral movement of the former causes the latter to rotate and swing the roof round sufficiently to expose the hearth completely. The drop-bottom bucket containing the charge is then lowered into the shell. A tightly-packed charge enables the furnace to hold 20 tons without re-charging. As the bucket is swung clear, the roof returns to its original position and is lowered on to the shell.

The complete lifting ram cylinder is mounted entirely separately from the furnace body, which means that the furnace shell is not subjected to severe stresses when the roof is lifted, and also prevents the formation of a hot spot on the cylindrical body, through impediment to uniform heat dissipation.

All phases of the roof lift and swing mechanism are interlocked to ensure correct sequence of operation, and to prevent the tilting of the furnace except when the roof is in the working position, or the lifting of the roof when the furnace is tilted.

The furnace is designed for a 45° forward tilt for pouring and a smaller backward tilt for slagging,

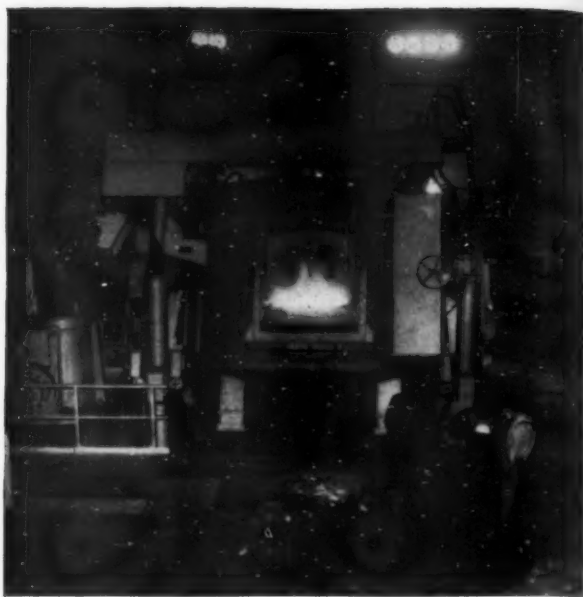
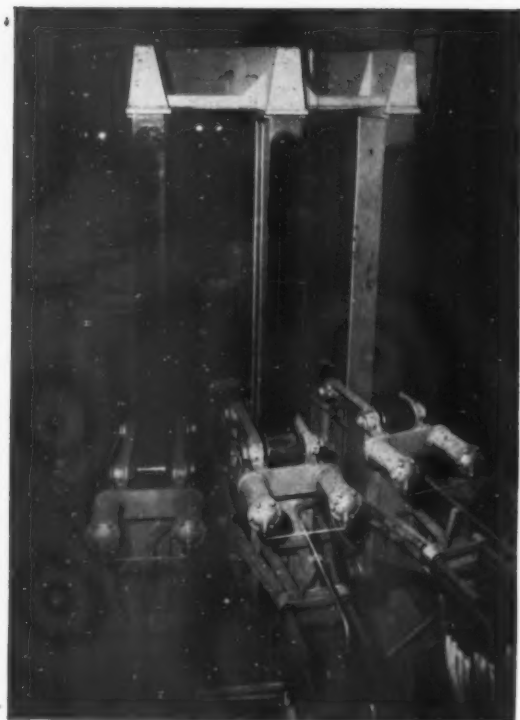
tilting being effected by means of steel rocker trunnions gearing into horizontal tracks on either side of the shell. An indication of the solid construction is given by the weight of the tilting gear, which exceeds 12 tons. The tilting rockers are operated by hydraulic rams, oil pressure being supplied by a self-contained motor pump unit which also serves the roof-lifting mechanism. A notable feature of the general design is the removal from beneath the shell of all mechanism, thus obviating the risk of fouling or of damage due to a metal break-through.

Electrode Gear and its Control

Three 14 in. diameter graphite electrodes supplied by British Acheson Electrodes, Ltd., are held in water-cooled high-conductivity copper clamps and project vertically through the furnace roof. A special feature of the clamp design is the fitting of a pneumatic mechanism so that they can be opened and closed by remote control, thus enabling the electrodes to be slipped very quickly and easily when a new charge is loaded, or whenever the electrode height requires adjustment.

The clamps are mounted on the extremities of horizontal arms which carry the conductors for electric power and cooling water. The arms, which are of rigid construction and designed to minimise eddy-current losses, are connected to the vertical masts by carriages or crossheads. The latter are fitted with hardened-steel adjustable rollers in anti-friction bearings which engage with flat machined surfaces on the masts. In this way a smooth up-and-down movement, without lateral play, is obtained. The electrode masts are mounted at the rear of the furnace shell in the heavy steel eye-casting which also carries the roof supporting beams.

The electrode carriages are suspended on flexible steel cables passing over ball-bearing sheaves and leading through ducts in the furnace foundations to individual



Rear view of the furnace starting to tilt; the clear space beneath the shell can be seen.

The pneumatic electrode clamping gear.

winches, located beneath the melting shop floor and driven, through gearing, by D.C. motors rated for frequent reversing duty. The winch drums are provided with specially designed friction bands over which the suspension cables pass to terminate in counter weights.

An important feature of this furnace installation is the incorporation of B.T.H. Amplidyne regulation gear. The Amplidyne is a special type of D.C. generator, in which the field excitation is controlled from opposed voltage and current components of the furnace power circuit and produces instantly a corresponding, but greatly magnified, variation in the generator voltage applied to the winch motors. Thus, the latter are energised in proportion to the degree of out-of-balance in the furnace power circuit, and the electrodes move rapidly to compensate for large changes, and proportionately more slowly for small variations. The system thus provides smooth, stepless movement of the electrodes, with maximum speed and without hunting, for correcting any deviation from desired arc conditions. This is achieved without the use of relays and gives maximum sensitivity and accuracy of control.

Power Equipment

Provision of power equipment has been made through Birlec, Ltd., by various electrical concerns. The Parsons 6,000 kVA transformer operates from a primary 11,200-volt 50-cycle 3-phase supply and provides eight secondary tapplings. An on-load tap change switch is provided, arranged for off-load operation. Both motor-operated push-button control and manual control are provided, and an illuminated indicator on the furnace instrument panel shows the position of the tapping switch.

In order to withstand heavy current fluctuation, the transformer is constructed with specially-braced wind-

ings: it is conservatively rated to give an oil-temperature rise of 50° C. under continuous full load. The water-cooling system is equipped with a temperature alarm device to warn the operator immediately of an unsafe oil temperature.

The Reynolle main switch is a metal-clad, 400-amp, compound-filled single busbar switch panel. It has a rupturing capacity of 150 MVA at 11,000 volts, 3-phase, and is arranged for solenoid operation. An interlocking relay ensures that the breaker trips whenever the transformer tap change operates, or when any of the individual furnace interlocks make contact.

Control Panel

All controls and metering are centralised in one black Sindanyo control board, which is mounted in the wall of the transformer substation and is easily accessible to the working area around the furnace. It contains the necessary indicating lamps for electrode voltage and auxiliary electric supplies, the transformer tapping switch indicator, an electric clock, a voltmeter and multi-point switch for electrode voltage, an ammeter for each electrode circuit, and a meter to show the power supplied to the furnace. It also carries the required control switches for the electrode winch motors, hand-operated rheostats for obtaining the correct arcing conditions, and isolators for the auxiliary A.C. and D.C. supplies—for instrument operation, etc. A telephone on the board connects with the main Hadfield switchboard.

THE theme of the Sixth Annual Conference of Incorporated Plant Engineers, which is to be held at the Palace Hotel, Southport, from May 20th to 22nd, will be "Management and the Plant Engineer."

Some Practical Notes on Casting of Ingots for Seamless Tubemaking*

By G. Bowmant†

The requirements for, and practical difficulties of, casting killed steel for use in the rotary forge tubemaking process are outlined, and the formation of ingot cracks discussed, with suggestions as to the cause and possible methods of prevention. The effect of the pipe cavity during rolling is illustrated, and it is shown how the ill effects are eliminated by the use of straw for hot topping. The occurrence of blowholes and methods of prevention are described.

M R. N. H. BACON once said that the pit-side was the "Cinderella of the melting shop." "There could be no doubt," he said, "that the casting-pit practice had a very important bearing on the measure of success achieved by the melting shop, and it was probably fair to say that this section of the open-hearth plant had not received the attention that its importance warranted." While this statement was undoubtedly justified, it must be said that in recent years steelmakers have become more alive to the damage which can be done to good steel through faulty casting practice. Also, more technical attention and study has been devoted to this aspect of steelmaking with the object of developing improved techniques.

Since the introduction of seamless tubemaking, the Company with which the author is connected has been very conscious of the importance of casting practice, and has devoted considerable time and money to the study of this subject. However, this work has always been hindered by the lack of a reliable method of assessing ingot quality by any non-destructive test, the assessment having depended to a large extent upon the incidence and type of defects occurring on the rolled or forged product and, since certain defects can occasionally arise from faults in these processes themselves, this method of assessing the value of variations in casting practice has its limitations. It is considered fair to say that while steels have a variable tendency to tear during forging, variations in forging practice can result in a varying tendency to tear the steel. Therefore, to assign the responsibility for certain defects is sometimes extremely difficult, if not impossible. If this method of assessment is being used, it is undoubtedly necessary to study the particular forging process involved in conjunction with the steelmaking and casting practice.

Although the author and his associates have, of necessity, used this method of assessment extensively, for the reasons given, the present paper is confined to items of work where the results could be more definitely measured. The investigations reported concern the casting of ingots for seamless tube manufacture by the rotary forge process, as practised at the Clydesdale Steel and Tube Works of Messrs. Stewarts and Lloyds, Ltd.

The steel plant has a capacity of approximately 3,250 tons per week, and the entire tonnage is devoted to

killed-steel ingots suitable for direct processing in the tube plant. The steels vary in composition from 0.1% to 0.45% carbon and from 0.4% to 1.3% manganese. The ingots, which are all cast uphill, are of the round fluted type, and vary in diameter from 7½ in. to 21½ in. The weight in each diameter varies considerably, since the ingots are cast to suit the length of tube ordered, because there is no intermediate rolling process; overall, the ingot weight may vary from 5 cwt. to 50 cwt. In view of the absence of any opportunity to dress or desurface after intermediate rolling, the maintenance of a high quality of cast ingot is essential. When this is considered in conjunction with the wide range of sizes and weights to be dealt with, it will be appreciated that the casting problem involved is somewhat different from that which presents itself in the normal steel plant. Consequently, more than usual attention has been paid to casting practice for many years, and special facilities have been provided in order to maintain the high standard of ingot necessary for this type of tubemaking.

Casting is carried out in separate buildings at right angles to the melting shop, with the object of avoiding contamination as far as possible. These buildings are provided with sunken casting pits and the ladles are brought from the melting shop in ladle cars which run over the pits. After each cast, the moulds are transferred to other buildings where facilities are provided for examination, cleaning and coating. After cooling, each individual ingot is examined carefully and, when necessary, dressed.

In the course of day-to-day checking of quality, both in tube and steel plants, interesting features of this type of ingot have been observed, and, in certain cases, have led to experiments aimed at improving quality. The object of this paper is to describe some of these features, and to show how they are affected by experimental changes in practice; also, to indicate the conclusions which have been drawn from the experiments.

Teeming speed is undoubtedly of paramount importance, and it is proposed to make some general comments on its effect before dealing with the more detailed points grouped under the following headings: (1) cracking, (2) cavitation and crusting, and (3) porosity.

Teeming Speed

As has been stated, all the ingots concerned are teemed uphill. The moulds are filled in groups, each group being located on one large bottom plate and fed from a central feeder into which the molten metal is

* Paper presented at a meeting of the West of Scotland Iron and Steel Institute on 20th February, 1953.

† Of Stewarts and Lloyds, Ltd.

poured from the ladle. Depending on the size of ingot being cast, a 70-ton heat may be spread over anything from six to 12 plates, and the total time of teeming may be as high as 50 minutes. Obviously, if an ordinary clay nozzle were used and the same number of moulds were set on each plate, the variation in teeming speed from the beginning to the end of the cast would be enormous, and the consequences would be disastrous.

It is customary to use a composite type nozzle, the upper portion of which is magnesite and the lower portion fireclay. The internal diameter of the two sections can be varied, but normally the magnesite is $\frac{1}{8}$ in. larger than the fireclay. In this way the variation in rate of discharge from the nozzle is minimised. A wide range of nozzle sizes in $\frac{1}{8}$ in. steps is available, so that the teeming speed can be adjusted to suit all ingot diameters.

Variations in the rate of discharge from the nozzle can be compensated for by varying the number of moulds set per plate, and the same method can be used, when different diameters of ingot are being cast from the same ladle, in order to obtain the most suitable teeming speed for each diameter. This method is used frequently in experimental work for obtaining a few ingots cast at other than the standard speeds. It will be appreciated that with this practice the rate of discharge from the nozzle does not bear a constant relationship to the rate at which the metal rises in the moulds. The rate of rise is the important factor: it is measured directly in "inches per minute" and is referred to in these terms.

Within reasonable limits, the higher the teeming speed the better the ingot in all but one respect, namely, the incidence of cracking. This has been proved beyond any shadow of doubt and, of course, the effect of teeming speed on ingot cracking is well known. It is easy, therefore, to determine the optimum teeming speed for any size of ingot; it is the maximum speed at which the losses due to cracking remain within economic bounds.

Until a few years ago, the tubemaking process necessitated the use of round ingots, which are more prone to cracking than any other shape. Immediately developments in tubemaking made it possible, a twelve-sided fluted design, as shown in Fig. 1, was adopted, and the standard teeming speeds increased.

Apart from one major advantage from increased teeming speeds, to be dealt with later, improvements arise in the following respects:—

- (1) there is less danger of momentary arrests in the rising metal and the resultant lapping or rippling of the ingot skin;

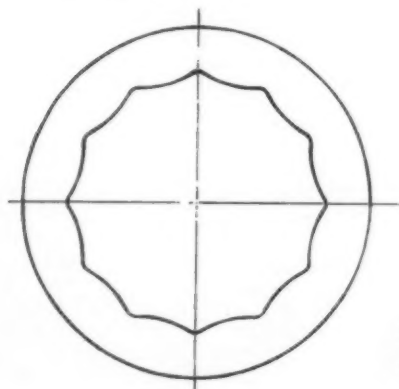


Fig. 1.—Twelve sided fluted design of ingot mould.

- (2) there is less tendency for eroded refractory to be trapped in the skin of the ingot;
- (3) the chill zone is much cleaner and less pronounced;
- (4) there is less segregation in the columnar zone, due presumably to the greater washing action of the faster flowing metal; and
- (5) the ladle emptying time is reduced with a consequent reduction in lining wear.

It is, therefore, inevitable that the aim must still be "higher teeming speeds" and, since cracking is the limiting factor, some consideration has been given to the mechanism causing this defect.

Ingot Cracking

The photograph shown in Fig. 2 illustrates the type of longitudinal ingot crack involved. It was decided that an attempt should be made to determine when longitudinal ingot cracks occur, as existing knowledge was limited to the fact that such cracks are usually visible when an ingot is stripped. The procedure adopted was to fill at about four times the normal teeming speed and to use a round mould so that there would be a very strong cracking tendency. In addition, a tangential runner entry was used so that the rising metal swirled. In this way an inverted cone formation was maintained on the surface, thus ensuring that slag and refractory material would be kept away from the mould/steel interface and so avoid entrapment in the chill layer. The diameter of the mould used was $12\frac{3}{4}$ in., and the ingots cast weighed approximately 12 cwt.

It was found that the mould could be stripped quite quickly provided the runner entry was not disturbed, otherwise bleeding took place at that point. The time from the finish of teeming to stripping the mould was reduced on each succeeding trial, but always the ingot was found to be cracked, even when that time was reduced to as low a figure as 40 seconds. This established one fact not previously known, namely, that the crack occurred almost immediately teeming was completed, and the total time taken to fill the mould did not exceed one minute.

The following points were observed in all cases: (1) no bleeding occurred; (2) there was distinct necking at the crack; and (3) the cracks always occurred in a hot longitudinal band between two cooler bands. It was concluded that the cracks were caused by circumferential stresses set up by the contraction of the two cooler bands which caused the ingot skin in the hot band to neck and ultimately break.

Consideration was given to the possible cause of the very uneven cooling, and when it was found that the mould was $\frac{1}{16}$ in. out of round, it was thought that this might be causing exaggerated partial contact along the cooler bands. The mould was machined to a true round but the same phenomenon continued to occur.

Numerous methods of combating the uneven cooling were tried, but only two were found practicable, and these were both based on reducing the rate at which the molten metal was chilled. The first was to pre-heat the mould, the average temperature being increased in each succeeding trial. Only when a temperature of 250°C . was reached was an ingot made free from cracks. This was repeated several times and the results confirmed that cracking could be avoided by the use of hot moulds.

The other method used was to line the mould with template paper and so reduce the rate of heat transfer from ingot to mould. Ingots free from cracks were

made by this method on several occasions. In all cases the ingots were stripped between one and two minutes after finishing teeming and, although there was still evidence of uneven cooling, the temperature difference between different parts of the ingot was of a much lesser magnitude than when unlined moulds at the normal temperature were used.

These experiments seem to have established the following interesting facts:

- (1) that ingots of the type used can be stripped almost immediately after filling;
- (2) that the type of cracking being studied occurs either during filling or immediately afterwards;
- (3) that under normal casting conditions the temperature differences found on the ingot surface are very great;
- (4) that the cracks occur in the slower cooled bands of the ingot; and
- (5) that reducing the cooling rate of the ingot skin results in more even cooling and inhibits ingot cracking.

It might be suggested that the phenomena observed in these experiments were associated in some way with the swirling of the rising metal which resulted from the use of a tangential entry. While this cannot be confuted from the evidence available, the author does not believe this to have been the case, and considers that it was important to use this method and so avoid the danger of any entrapped material affecting the cracking tendency.

The intervals between finishing filling and stripping were much shorter than might have been anticipated from a study of the existing literature. It might be that the relatively light ingot used had some influence in this connection, and that the mould was stripped before complete separation had taken place. Nevertheless, any remaining partial contact must have been very slight to allow removal of the mould without transverse rupture of the ingot skin.

The results of previous work have always led to the recommendation that the rapid formation of a thick chilled skin should be encouraged in order to resist the bursting effect of the ferrostatic pressure from the still-molten interior, and the localised stresses that might be set up in the later stages of cooling. However, in the case quoted, cracking took place at a very early stage without any sign of bleeding, which suggests that such cracking does not result from internal pressure; in fact, in previous work where bleeding has occurred, it does not necessarily mean that the crack has resulted from such internal pressure. Nor is there any confirmation that a thick chill zone counteracts localised stresses, and it may well be that the crack has taken place before the chill zone is completely formed.

Earlier experience led the author to favour the theory that partial contact was the cause of cracking, due to the tension set up between two points where the ingot skin continued to adhere to the mould after the intervening portion had separated. The fact that slower cooling prevented cracking might be claimed to support this theory, if the slower cooling encouraged the ingot to separate from the mould in a more regular manner. However, it is doubtful whether the ingot skin ever adheres tightly enough to the surface of the mould to set up the necessary tension unless there are irregularities such as crazy cracking on the mould wall. The author is of the opinion that the type of longitudinal cracking



Fig. 2.—Longitudinal ingot crack.

under consideration is entirely due to uneven cooling of the ingot skin immediately after casting, and that the cure must be found through improved methods of controlling this factor. The experiments suggest that this might be achieved by reducing the rate of chilling by some method suitable for production practice.

Cavitation

When considering the freezing of a killed-steel ingot, one thinks of the effect of the inevitable pipe cavity. Invariably the shape, depth and accompanying segregate are taken into account when the amount of discard from the rolled product is being estimated. In the normal cogging practice, the extent to which the cavity and segregate exist in the bloom determines the amount to be discarded at the shears. Thus, every attempt is made to minimise the dimensions of the pipe cavity, particularly the depth within the ingot. For this reason, hot topping is practised extensively and in a large variety of ways, many of them comprising specific designs of refractory tops for moulds.

In the rotary forge practice, the pipe cavity is also an important factor. In casting ingots for this method of rolling it is impossible to use the refractory hot topping system owing to the varying ingot lengths which are necessary in casting for tube orders. Also, the approach to the cavity problem is slightly different. The length of cavity is not so important for this purpose as it is in the case of the cogging mill, but the cross-sectional area is important. For normal cogging, there is no mechanical method for compressing the length of the cavity and the cross-sectional area is relatively unimportant. For rotary forging, the cavity can be compressed adequately, provided the cross-sectional area is small enough to be covered entirely by the piercing punch. This is illustrated in Fig. 3. Fig. 3a shows a killed ingot teemed normally and having the usual top bridge and one secondary bridge across the pipe cavity. Fig. 3b illustrates the result of the pre-piercing operation, showing the compression of the cavity, with two lines of segregate indicating the new position of the cavity bridges. Fig. 3c shows the result of the next operation which elongates the piece and, of course, the lines of segregate, which do not weld. Fig. 3d shows the

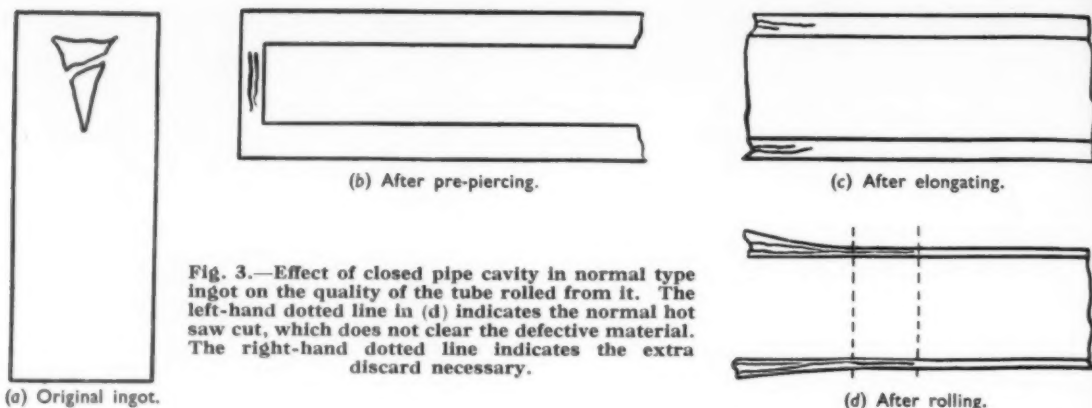


Fig. 3.—Effect of closed pipe cavity in normal type ingot on the quality of the tube rolled from it. The left-hand dotted line in (d) indicates the normal hot saw cut, which does not clear the defective material. The right-hand dotted line indicates the extra discard necessary.



Fig. 4.—Sulphur print of "bell end" of steel tube made from normal ingot.

finished tube, in which two points are indicated by dotted lines: (1) the normal hot-saw cut, and (2) the further discard required to remove the segregate. The point at which the normal saw-cut is made is determined purely by tube-making practice. The thick walled end of the tube shown in Fig. 3d is called the "bell end": this has to be discarded and the normal cut is made so that only the thickened portion is removed. The normal type of ingot frequently gives rise to unsoundness beyond this point, as shown diagrammatically in Fig. 3d and in the sulphur print Fig. 4. When this occurs, a further discard is necessary.

In considering how this loss could be avoided, it was thought that if the bridges, particularly the thick top bridge, could be eliminated, any unsoundness would be concentrated still nearer the end of the pre-pierced ingot shown in Fig. 3b, and so have less tendency to spread along the tube. This suggested that some form of hot topping was the possible remedy, and experiments were made with various materials ranging from anti-piping compound to circular pads made from different substances. The most efficient method to give an open cavity was found to be a circular pad made by compressing the residue from the effluent from paper works. These pads were made in hydraulically-operated dies, dried in ovens at controlled humidity, and dropped into the moulds before teeming commenced.

Trials using these pads gave the desired reduction in crop loss, and Fig. 5 repeats the diagrams in Fig. 3, but illustrates the effect of the open cavity. In this case, the heavy segregate at the base of the cavity is compressed to the end of the ingot after pre-piercing. Thus, in cutting at the hot saw, the segregate is removed completely, as illustrated by the sulphur print in Fig. 6.

During the course of these experiments it was found that the quality of the raw material for making the pads varied considerably, and, consequently, the mechanical

strength and drying properties were variable. Also, it was found that the pads absorbed moisture during storage, and the generation of gases from this source during teeming was undesirable. A second effect of this moisture absorption was the tendency for the pads to disintegrate during teeming and for pieces to become embedded in the ingot.

While these disadvantages were not serious enough to rule out the possible use of pads on a production scale, the search for other materials was continued. One possible substance was straw, the use of which was referred to in an article in the December, 1951, issue of *Blast Furnace and Steel Plant*. Preliminary experiments using a few pounds of straw packed loosely into the moulds prior to teeming gave promising results, but it was found advisable also to place loosely-fitting steel plates over the moulds in order to retard the burning of the straw.

The straw began to burn immediately the molten metal entered the mould, and the heat generated in this way appeared to be sufficient to keep the top surface of the metal molten during teeming and for a short time afterwards. The burnt residue from the straw acted as an insulator and assisted in this direction so that the fluid steel could sink back to form the contraction cavity and produce an open-topped ingot as shown in Figs. 7 and 8.

A large-scale trial was carried out to compare ingots cast in the normal way with ingots cast with pads and others cast with straw. As might be expected, the use of straw on this larger scale revealed several difficulties, such as ignition of the straw by sparks prior to the commencement of teeming. Consequently, all the ingots obtained were not as perfect as the examples which have been shown. Nevertheless, the great majority were substantially open topped and considered suitable for the trial.

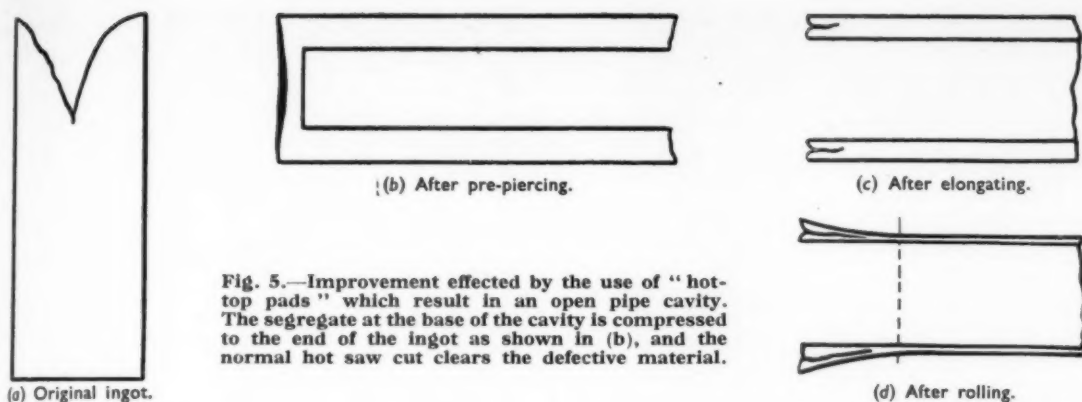


Fig. 5.—Improvement effected by the use of "hot-top pads" which result in an open pipe cavity. The segregate at the base of the cavity is compressed to the end of the ingot as shown in (b), and the normal hot saw cut clears the defective material.



Fig. 6.—Sulphur print of "bell end" of steel tube made from "hot-top" ingot.

These ingots were rolled in mixed batches and a careful check was made on all additional cropping which was required after the normal tube "bell end" was removed.

These additional cuts were measured and converted to a percentage of the ingot weight. This can be considered as a scrap loss which might otherwise have been good tube. The losses on each batch of ingots in the different categories is shown in Fig. 9, from which it will be seen that the open-topped ingots, either from pads or straw, resulted in a saving of approximately 1%, which is appreciable under present-day conditions.

Crusting

Reference was made earlier to a major cause of defects which was associated with teeming speed. This is frequently referred to as "crusting" and consists of deoxidation products and eroded refractory rising to the

surface of the metal, oxides resulting from oxidation of the exposed top surface and frozen steel. Anyone who has had experience in uphill casting will have seen this and know how it tends to migrate towards the mould wall and how it can, on occasions, be trapped in the rising metal. This crust, or skull, gradually increases in size as the metal is rising, so that the greatest danger of entrapment is near the top of the ingot. It will be appreciated that a piece of this trapped in an ingot must give rise to a comparatively serious defect in the final product.

Such defects in cold ingots are not too obvious and may easily be missed. They are, however, associated with a slight lap which although apparent on the ingot surface does not look like a serious defect; an example of this is shown in Fig. 10. Ingot inspectors must suspect all laps and examine them further with the use

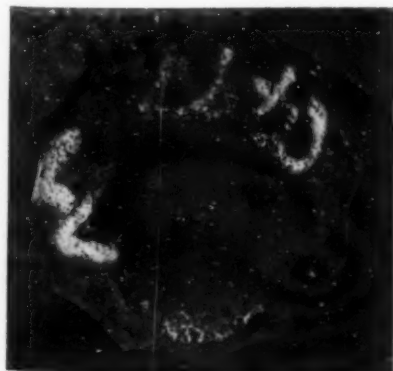


Fig. 7.—Cavity in open-topped ingot.

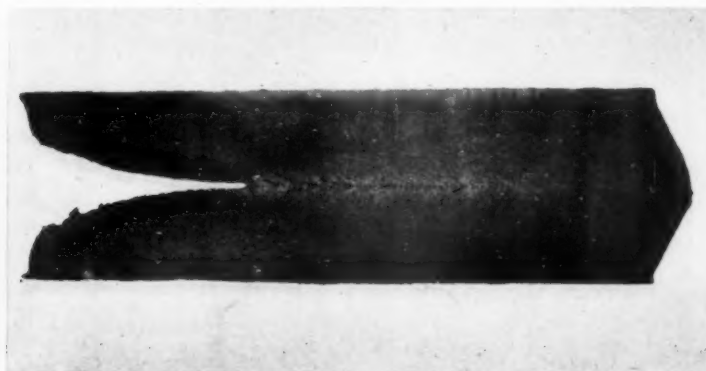


Fig. 8.—Sulphur print of longitudinal section of open-topped ingot.

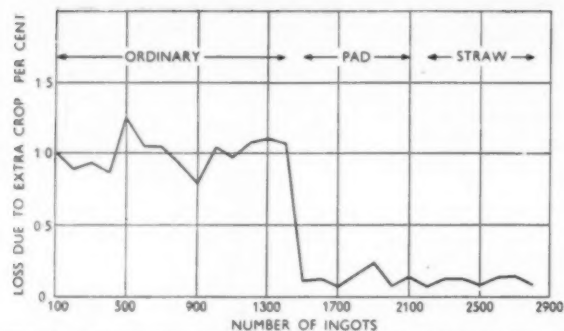


Fig. 9.—Effect of use of "hot-top pads" on losses due to extra crop.

of an oxy-acetylene torch. The same lap as shown in Fig. 10 is shown again in Fig. 11 after torch desurfacing. It will be seen that the defect is then quite obvious. Such defects are frequently of sufficient depth to necessitate scrapping the complete ingot.

Higher teeming speeds have always been a counter to this source of trouble, both by reducing the time available for the crust to form and by tending to keep it away from the mould wall. Unfortunately, the maximum teeming speed permissible without serious danger of cracking is not high enough to eliminate this defect. Nevertheless, the incidence is substantially reduced by using the highest teeming speeds which can be permitted. Another factor which is helpful in this direction is the use of a good mould coating. The gas evolved from the coating at the mould/steel interface tends to keep the crust away from the mould wall although it does not in any way inhibit its formation.

Obviously the complete answer is to prevent the formation of such crusts, and with this object in view, casting was carried out with the tops of the moulds closed except for a small vent hole. The intention was to reduce the heat loss from the top surface and maintain a reducing atmosphere within the mould. It was felt that if this could be done to a sufficient degree, the formation of both frozen metal and oxide would be

prevented. Results showed that while there was an improvement, this cure was only effective to a limited degree.

The subject of crusting has been dealt with following that of cavitation because the use of straw and a plate over the mould has also proved the most effective cure for crusting. A great many ingots cast by this method have been desurfaced to a depth of 1 in. by machining and the number of entrapped crusts found has been negligible.

It must be emphasised that what has been said here regarding the use of straw has been based on experimental work, although some of the trials involved large numbers of ingots. It may be that in full-scale production unforeseen difficulties would arise.

Porosity

Porosity can, and does on occasions, occur in killed-steel ingots which have been teemed uphill. The blowholes are subcutaneous and consequently cannot be detected or studied by examination of the as-cast ingots. The following three methods have been used to expose and study porosity:—

- (1) longitudinal sections have been cut and examined, but this only revealed a very restricted area of ingot skin, and did not justify the excessive amount of machining involved;
- (2) ingots have been desurfaced in a lathe, and if this is done in small steps it is quite an effective method of examination, particularly for round ingots; examination of fluted ingots by this method is not so successful;
- (3) oxy-acetylene torches have been used to desurface ingots, and this method is quite effective, but is more suitable for exposing sample areas than for examination of a complete ingot surface.

Methods (2) and (3) have been used extensively to expose and study porosity. Fortunately, or unfortunately, depending on whether one is interested in production or investigation, blowholes are not present in all ingots, and very large numbers have had to be examined in order to obtain a reasonable amount of evidence.

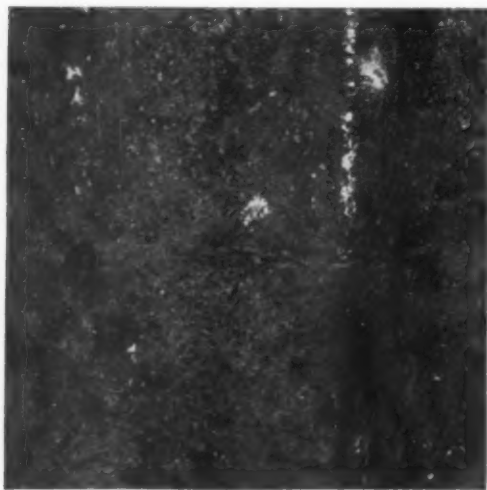


Fig. 10.—Lap associated with trapped crust in bottom-poured ingot.



Fig. 11.—The same lap as Fig. 10 after oxy-acetylene torch desurfacing.

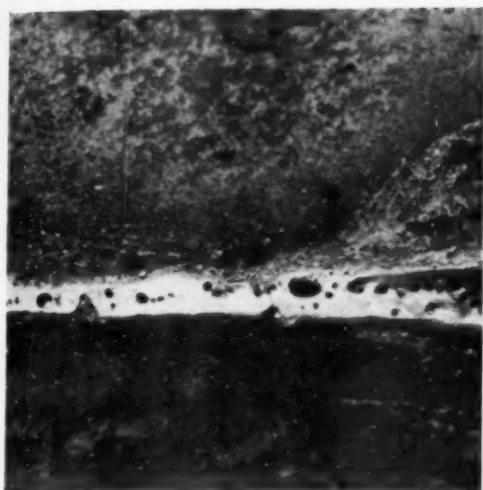


Fig. 12.—Subcutaneous cavities associated with chilling.

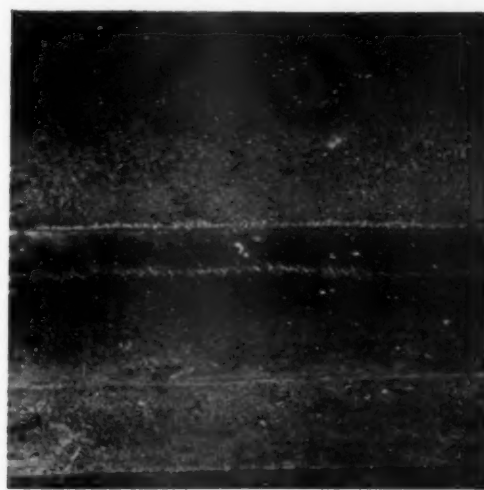


Fig. 15.—Porosity associated with slaggy material.

In the course of this work, two distinct types of blowholes were identified on numerous occasions. Although subcutaneous, both types were near enough to the surface to be removed by either method (2) or method (3), above, or to be exposed by scaling during reheating. Fig. 12 shows the first type, which was sometimes found at the bottom corner of an ingot. The shape and distribution of these holes will be noted and, although it cannot be ascertained from the photograph, they were completely free from contamination of any kind. When these holes or cavities were found in ingot sections which had been etched and sulphur printed, it was noticed that they were always located where the chilling appeared to have been most severe as judged by the thickness of the chilled layer.

The first metal gushes into the mould with a fountain effect and splashes into the bottom corners, where it freezes very rapidly due to the combined effect of the mould and the bottom plate. It will be seen from the normal type of entry shown in Fig. 13, that the metal first chilled in these corners is not likely to be reheated by molten metal subsequently entering the mould. It was, therefore, concluded that such holes might be a series of small contraction cavities resulting from the rapid chilling. It is not unusual for the first surge of metal entering a mould to go mainly towards the one side, and this might well account for the holes being associated with the thickest chill.

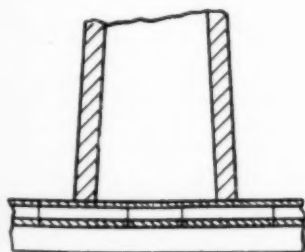


Fig. 13.—Normal type of entry to bottom poured mould.

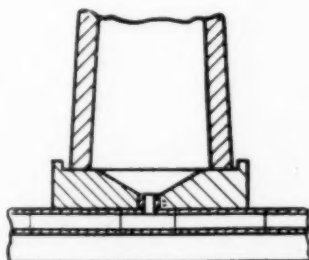


Fig. 14.—False bottom plate designed to avoid porosity.

On this assumption, a new false bottom plate was designed with the object of avoiding such holes; this is shown in Fig. 14, from which it will be seen that this was introduced between the main bottom plate and the mould. The intention was that the first surge of metal should be confined in the conical portion, so that any rapid chilling which took place would be counteracted by the further metal entering the mould; also that a pool would be formed in the cone, and that the metal would flow slowly and smoothly from this into the bottom corners. This arrangement also ensured perfect centring of the mould over the inlet, thus reducing the danger of uneven distribution of the molten steel.

A large number of ingots were made with this set-up, and the results were very much as expected. Ingots cast in this way showed a very much lesser tendency to have unsound areas at the bottom corners. It is felt that even better results might have been obtained had the diameter at the base of the cone coincided with the diameter at the bottom of the mould.

The other type of porosity encountered occurred in patches on the body of the ingot and mainly in the upper half. An example of this type is shown in Fig. 15. Each hole contained a small bead of slaggy material of the following approximate composition:—

Silica	41.0%
Alumina	9.0%
Ferric oxide	8.0%
Manganous oxide	41.0%

This type of porosity was found mainly on one side of the ingot and again was associated with the thickest portion of the chill layer. It has been established that variation in the thickness of the chill, and, therefore, the incidence of this porosity, is aggravated by an off-centre inlet to the mould, the thick chill being on the side farthest from the inlet.

In looking for a possible source of the slaggy material occurring in these holes, it was found that, after use, the mould surface had small globules adhering to the surface. The analysis of this material was:—

Silica	15.2%
Alumina	8.5%
Ferric oxide	64.4%
Manganous oxide	11.2%

These globules may be the result of erosion from the runner bricks and/or ladle lining, and may be deposited on the mould surface during filling. Subsequent ingots from such a mould have thus two sources of pick-up of this material, that is, erosion by the current teeming and pick-up from an improperly cleaned mould. When this material is trapped by solidifying metal the $\text{FeO} + \text{C}$ reaction takes place, leaving the residual aluminomanganese silicates in the form of a bead. If the mould is cleaned and coated efficiently, there is a distinct decrease in the deposition of these globules on the surface and also a reduction in the pick-up by the metal.

To minimise the second type of porosity it is essential to clean and coat the moulds properly, to centralise the moulds over the riser holes properly, and to keep the metal as fluid as possible during teeming, to ensure

the rising of slaggy material to the top of the ingot.

Conclusion

The casting of killed-steel ingots to meet the conditions specified in this paper requires that the greatest care must be taken with every detail of casting practice. The importance and effect of many items such as the cleanliness and coating of moulds, accuracy in the setting of moulds and runners, control of teeming speed, etc., has been shown. The practical investigations and experiments described have, also, demonstrated the effect of open contraction cavities on tubemaking and how these can be obtained when the normal methods of hot-topping are not practicable.

The frequent references to ingot cracking and teeming speed throughout these notes will have emphasised how important these factors are considered to be. It is hoped that the experiments on cracking and the theory put forward will prove a useful contribution to the knowledge of this important subject.

Corrosion Testing Lecture Course

A COURSE of evening lectures on "Corrosion Testing" will be delivered at 7 p.m. on Wednesday, March 18th and Tuesdays, March 24th, April 14th, 21st, 28th and May 5th, 1953, at the Northampton Polytechnic, St. John Street, London, E.C.1. The subjects to be dealt with are listed below, together with the name of the lecturer.

March 18th: *General Principles of Corrosion Testing*, by S. C. Britton (Tin Research Institute).

March 24th: *The Preparation of Specimens*, by F. A. Champion (The British Aluminium Co., Ltd.).

April 14th: *The Atmospheric Corrosion of Uncoated Metals*, by J. F. Stanners (B.I.S.R.A.).

April 21st: *The Immersed Corrosion of Uncoated Metals*, by G. H. Botham (The A. P. V. Co., Ltd.).

April 28th: *Tests for the Selection of Protective Coatings*, by S. C. Britton (Tin Research Institute).

May 5th: *The Assessment of Corrosion*, by F. A. Champion (The British Aluminium Co., Ltd.).

The fee for the course is £1 and enrolment can be effected by personal attendance at the Polytechnic or by post. Those enrolling by post should supply the following information: (a) name and address; (b) name of employer; (c) qualifications (e.g., B.Sc., Higher National Certificate, etc.); and enclose the fee and a stamped addressed envelope.

Unique Ventilation System at Nickel Mine

THE only one of its type in Canada, a towering 20-ton exhaust fan has been installed by The International Nickel Company of Canada, Ltd., to ventilate the underground workings of the new caving project at its Creighton Mine in the Sudbury District of Ontario. This method of mining involves the under-cutting of ore far underground, followed by its caving and disintegration, and as the Creighton project took shape on the drawing boards, primary consideration was given to devising a ventilation system which would provide for the flow of a steady stream of fresh air through the slusher drifts—passageways through which ore is drawn off after it has come through funnel-shaped boxholes beneath the mass of broken ore.

The giant vertical fan, driven by a 350 h.p. motor weighing 5 tons, ventilates the workings by a flow of fresh air at the rate of 300,000 cu. ft./min. The fan

draws the air down from the surface, directly through the caved or broken ore, circulates it through the underground workings and carries it back to the surface through a return shaft. It is at the top of this shaft that the fan is mounted. The fan stands 42 ft. above its concrete base, and the diameter at the inlet is 15 ft. The 124 in. impeller has 12 stainless steel blades which are adjustable in pitch through 25° to accommodate the load as the mining operation moves further away from the main return air shaft. The system is effectively servicing the project as it has been developed to date, and has ample capacity to handle ventilation needs under maximum operating conditions.

Northern Instrument Sales Office

A NORTHERN Sales Office for Smiths Industrial Instruments, Ltd., was opened recently at York House, 12, York Street, Manchester, 2 (Tel.: Central 0858). It will provide for all customer's enquiries concerning instrumentation, and will undertake distribution and service of the wide range of instruments supplied to the textile industry and industry generally.

Change of Address

THE BRITISH ALUMINIUM CO., LTD., have vacated their Branch Office and Warehouse at 66, Kirkstall Road, Leeds, 3, and have transferred their Branch Office to Martins Bank Chambers, Vicar Lane, Leeds, 1, to handle sales of unwrought and fabricated aluminium and aluminium alloys in Yorkshire and Lincolnshire. Mr. A. E. Heeley continues as Branch Manager, and the telephone number remains Leeds 28343, with the telegraphic address, as before, "Britalumin Leeds."

Anniversary Dinner

To celebrate their 21st birthday, Asbury, Brodie & Co., Ltd., distributors of electrical resistance materials, stainless steel, cadmium, nickel anodes, oxides and salts, etc., held a most successful dinner and dance at The New Inns, Handsworth, Birmingham, on Friday, February 6th. Among the principal guests were Mr. R. M. Parry, Managing Director of British Driver-Harris Co., Ltd.; Mr. I. A. Bailey, Managing Director of Henry Wiggin & Co., Ltd.; and Mr. George Tinker, Managing Director of Birlec, Ltd.

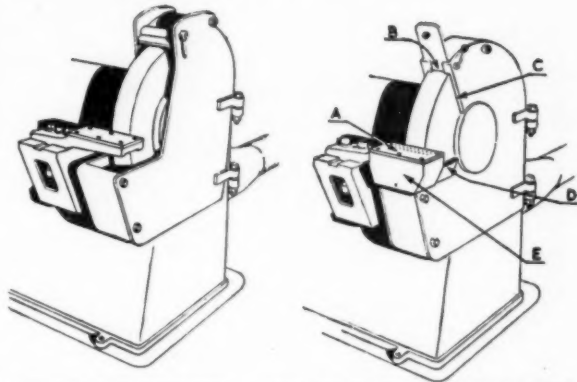
Steel Foundry Research on Grinding Machine Exhaust Systems

Major Development in Dust Control

OUTSTANDING improvements in dust suppression on stand or pedestal grinding machines as used in steel and other foundries are announced by the British Steel Founders' Association. These improvements apply equally effectively to units having wheels of high (9,000 ft./min.) and of medium (5,400 ft./min.) peripheral velocity and can be easily fitted both to existing machines and to new equipment. They have been shown to give a considerable reduction in the amount of dust escaping into the foundry atmosphere when compared with conventional hood design (Fig. 1).

The research work leading to these improvements has been carried out at the Dust Research Station established in Sheffield by the Research and Development Division of the B.S.F.A. during 1951, and has been sponsored by the Committee on Industrial Health of the British Steel Founders' Association. The work has been conducted with the co-operation of the Foundry Trades' Equipment and Supplies Association and of its Ventilation Committee, through which a series of 24 in. stand grinding machines of different manufacture has been made available for experimental purposes. As the work has progressed, keen interest has been shown by H.M. Inspectorate of Factories and by the Trade Unions, the Iron, Steel and Metal Dressers' Trade Society in particular.

Preliminary observations at the Dust Research Station were conducted using Perspex end-covers fitted to standard 24 in. grinding units, by means of which it was possible to observe, under appropriate conditions of illumination, the flow of dust-laden air inside the machine cowling. These observations revealed that air streams being drawn into machines of conventional design prevent dispersion within the cowling of the stream of dust-laden air produced by the grinding operation and cause it to adhere to and rotate with the periphery of the grinding wheel instead of being extracted through the exit-duct to the dust collector and



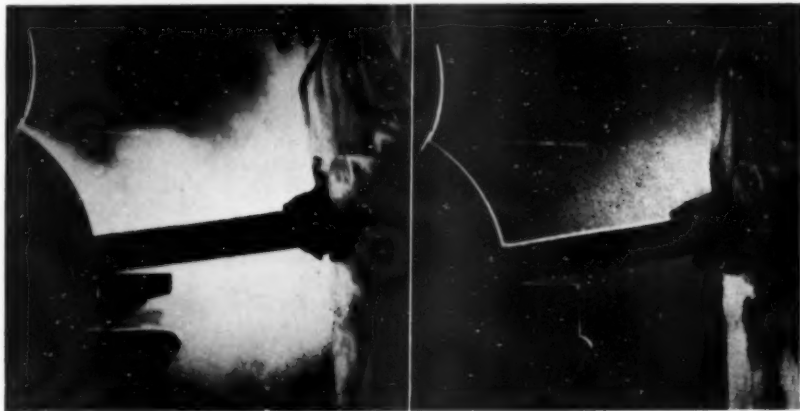
A—PERFORATED WORK-REST. B—GAP CLOSED BY EASILY ADJUSTABLE TOP FLAP. C—MINIMUM AIR GAP BETWEEN SIDES OF COWLING AND WHEEL. D—SPARK TRAP. E—ENCLOSED GAP BETWEEN COWLING AND WORK-REST.

Fig. 2.—Left: Design of conventional grinding machine hood. Right: Design resulting in improved dust suppression.

fan system. The dust stream adhering closely to the wheel is thus caused to emerge from the cowling in front of the operator and subsequently to be deflected by the work-rest and by the work itself directly into the breathing zone of the operator.

By controlling the ingress of air being drawn into the cowling by the extraction system, and by concentrating the effects of extraction solely upon the dust-stream, it has been shown that it is possible to reduce very substantially the amount of dust-laden air rotating with the wheel and thereafter emerging and reaching the operator. The measures adopted involve the design of a work-rest such that the effects of the extraction system are applied directly to the underside of the work-rest itself, thus bringing the extraction as near to the source of dust-generation as possible.

Fig. 1.—Left: The smoke cloud formed by the grinding of wood on a standard machine as supplied by the makers. Right: The reduction in dust emission due to the adjustments made in the design of the hood. The slight glare appearing above the operator's hands in the right-hand picture is caused by the lighting technique employed and is obscured by the dust itself in the left-hand picture.



Further modifications include reducing to a minimum the gap between the casing and the sides or flanks of the grinding wheel, together with an easily adjustable "gap-closer" at the point where the wheel emerges from the cowl immediately in front of the operator's face. This gap can readily be closed by the operator as the wheel wears.

At the same time, the work-rest has been altered to embody either slots or perforations which, together with the suction applied below the work-rest, effectively prevent the work-rest acting as a stripping mechanism for deflecting the dust-stream towards the operator's breathing zone before it enters the cowl. The complete recommendations are shown diagrammatically in Fig. 2.

In achieving their objective, the modifications have been made in such a way that the control of the dust has been brought as near as possible to the dust origin, have confined the dust-stream within the cowl itself and, last but not least, have involved no complicated innovations or alterations to the construction of the stand grinding equipment. The latter criterion has been regarded as being of prime importance, and has been rigidly observed throughout the development work in so far as only in this way could any design improve-

ments evolved be applied retrospectively to existing machines at small expense and with the greatest possible speed. Similarly, in relation to new equipment, the manufacturer is enabled to introduce a marked increase in inherent efficiency of his equipment with a minimum of departure from overall design, and with a minimum increase in cost of production.

It is more than likely that stand or pedestal grinding units in the future, not only for steel foundries but for other sections of the foundry industry, will incorporate as a standard feature the basic modifications that have arisen from this example of co-operative effort and applied research to a practical but very vital problem.

A film, recording the detailed stages of this research since its inception, is to be demonstrated at the forthcoming Annual Conference of the Institute of British Foundrymen. In view of the importance of its findings however, the British Steel Founders' Association has, with the concurrence of the Foundry Trades' Equipment and Supplies Association, and H.M. Inspectorate of Factories, which has been represented at meetings of the Foundry Trades' Equipment and Supplies Association's Ventilation Committee, agreed to make this statement public.

New Spanish Steelworks at Aviles Plant to be Supplied by British Firms

A POST-WAR investigation of the Spanish steel industry, undertaken by the Instituto Nacional de Industria and sponsored by the Spanish Government, showed that whereas the industry made one million tons of steel in 1929, the figure for 1950 was only some 700,000 tons, with little promise of any substantial increase so far as the existing works were concerned. Furthermore, in only one of the six large plants could any substantial expenditure be justified as showing a reasonable return on the investment.

The iron ore deposits in Vizcaya, rich and well-known as the basis of the Spanish industry, and also of a substantial portion of the British steel industry in the past, are now not nearly so plentiful nor so rich. The steel consumption per head of the population at present is below 50 lb. per annum—less than one-tenth of the corresponding figure for the United Kingdom. The investigators considered that additions to existing steelworks would not raise this figure above about 90 lb. per annum, whereas a figure of 165 lb. per annum was regarded as desirable. They concluded, therefore, that the solution of their problems lay not so much in piecemeal extensions of existing plants as in the establishment of a new integrated plant based on hitherto unexploited sources of coal and iron ore.

New Company Formed

As a result of these conclusions, the Empresa Nacional Siderurgica S.A. was formed in 1950 for the purpose of building and operating such a new plant on a site near the estuary of the Aviles river in Asturias. Essential conditions for the new plant were that it should not compete with existing works for the acquisition of iron ore of which they were already running short; it should

not reduce the already diminished export of iron ore; and it should not be dependent on imported coking coal. In the location chosen it will be based on Asturian ores and coal which have hitherto been little exploited.

The land was acquired and civil engineering work on its preparation has been in progress for about a year. The site is ample and provision has been made for the addition at a later date of a second and, ultimately, a third and fourth blast furnace. These will be accompanied by extensions of the steelmaking plant and rolling mills, and additional rolling mills for the production of merchant products, wire, rods, strip, sheet and tinplate. There is thus the possibility of an ultimate production of approximately $1\frac{1}{2}$ million tons of steel, and although this will probably not materialise for many years, good sense and foresight has been shown in planning for it now. Assuming a population of 30 millions, the additional output from the new works, together with existing works, will mean an increase in the production per head to approximately 125 lb., which will still be one of the lowest in Europe.

The first stage, producing an additional 350,000 tons per annum, is expected to start production in late 1956 or early 1957, when the industry's 1,650,000 ton output will comprise: (1) existing steelworks present output of 800,000 tons; (2) estimated increases in existing steelworks of 500,000 tons; (3) new production at Aviles of 350,000 tons. The plant involved will include a 1,000 ton/day blast furnace, open hearth steel plant, and bar and section mill.

British Plant

A group of British steelworks plant manufacturers have secured contracts representing a total value of

£10 million. Some of this equipment is to be made in Spain, but after making allowances for this, the sterling value is approximately £6 million.

A post-war development in the field of metallurgical plant manufacture was the formation of Metallurgical Equipment Export Co. Ltd., of London, a company owned and specially formed by several plant manufacturers to co-ordinate their export activities, and to offer foreign customers one source of supply for the wide range of equipment required in a modern metallurgical works. The Chairman of M.E.E.C.O. is Mr. D. F. Campbell and the negotiations in connection with Aviles have been conducted over the last two years by Mr. F. G. Connor, Managing Director, assisted by the Company's representatives in Madrid.

The securing of these contracts in the face of keen competition from France, Germany and Switzerland, is to be welcomed, not only for the value of the contracts themselves, but also as an encouraging sign of revival of the conditions of a quarter of a century ago, when the names of British manufacturers were household words in the Spanish iron and steel industry.

Ironmaking Plant

The ore preparation and blast furnace plant, which is being built by Head Wrightson & Co., Ltd., with the co-operation of the Fraser & Chalmers Engineering Works, consists mainly of four sections: (1) materials handling and blending plant; (2) sinter and slurry plant; (3) blast furnace plant; and (4) electrical equipment. The whole plant is designed for operation on Asturian ores enriched by the addition of oxide residues from the roasting of pyrites: the proportion of sinter in the burden will, therefore, be high.

Materials Handling and Blending Plant.

Most of the ores delivered to the plant will be sea-borne and will be discharged by two 500 tons/hr. unloading transporters on to a conveyor system for delivery to stock on to the crushing and screening plant. Rail borne materials will be discharged by wagon tippler and thence by belt conveyor to the ship unloading conveyor system. All ore will be crushed to minus 6 in. at the mine and further crushed to minus 2½ in. before use.

The blending plant will consist of four stockpiles each containing about 12,000 tons of ore stocked by means of conventional trippers. The ore will be reclaimed by Robins Messiter reclaiming machines. Screening before and after blending will eliminate all material minus ½ in. for sintering.

The flexibility of the conveyor system will permit the delivery of ore from ship to stockyard; from stockyard to crushing, screening and blending; from blending to high line; from ship to crusher; and from ship or stockyard direct to high line.

Sinter and Slurry Plant.

All ore fines minus ½ in. and all pyrites residues will be delivered to the sinter materials storage yard and thence to the bins. Coke breeze and flue dust will be delivered by rail to a track hopper, and then by conveyor to the screen in the sinter material building or direct to the rod mill surge bin. Feeder tables will feed materials from pre-selected bins to the gathering conveyor and then to the rotary mixers, together with the filter residue from the underflow thickener water.

The 20 wind-box sinter machine will be of the continuous type, 72 in. wide × 120 ft. long. The finished sinter will pass over a fixed bar screen into the sinter hopper, whence it will be fed to a 150 ton/hr. double skip hoist which will elevate it to the blast furnace high line bins. The undersize from the screen will be returned by vibrating tube conveyor and belt conveyor to the drum mixers. The thickener, sludge pumps and filters are designed for operation with two furnaces and the thickener will receive about 6,000 gal./min. of water when two furnaces are working.

Blast Furnace Plant.

The initial installation will consist of a single furnace having dimensions equal to the largest yet built in Europe. The ore and limestone from the materials handling plant will be delivered by belt conveyors to hoppers above the high line, and thence by transfer cars to the stockhouse bins, whilst coke will be screened at the ovens and delivered direct by conveyors to the coke bins. All raw materials other than coke will be discharged through air-operated bin gates into the scale car and then by twin skips, each of 250 cu. ft. capacity, to the furnace hopper. Coke will be discharged over vibrating screens to the weigh hoppers and thence automatically to the twin skips. Coke breeze from the screens is returned to the screening plant at the coke ovens.

Iron will be run into 75 ton hot metal ladles for transfer to the steel plant, while slag will normally be run into slag pits, whence it will be handled by excavators and dumpers on to waste land. Provision is also made for running slag into ladles if desired.

The gas cleaning plant comprises expansion-type primary dust catcher, centrifugal type secondary dust catcher and electrostatic fine cleaning plant. Clean gas from the fine cleaners will be used in the stoves, coke ovens, boiler house, sinter plant and cast house.

Electrical Equipment.

The general supply to the ore preparation and blast furnace plant will be at 6,300 volts 3-phase 50-cycles. Two feeders each of 8,000 kVA capacity will supply two sub-stations, one at the load centre of the port and ore blending area and the other at the blast furnace load centre. At these sub-stations, which will be ring connected, the power will be transformed to 380 volts, 3-phase, 50-cycles, or converted by mercury-arc rectifiers to 240 volts D.C. The precipitators will work at about 65,000 volts D.C. derived from oil immersed transformer rectifier units fed from the 380 volts, 3-phase supply.

Steelmaking Plant

The open hearth steelmaking plant, which will have an annual capacity of 336,000 ingot tons, will be the responsibility of The Wellman Smith Owen Engineering Corporation, Ltd., who will design and construct the three 300 ton tilting open hearth furnaces and the 600 ton active type hot metal mixer. These items will be of the most up-to-date design, as will the Wellman handling equipment, and the open hearth plant as a whole will conform to the best modern British steel-making practice. The handling equipment will comprise: two 100 ton hot metal cranes located in the charging bay along with two 4 ton low ground revolving furnace charging machines; two 140 ton casting bay

ladle cranes; and two 25 ton box lifting and magnet overhead travelling cranes operating in the scrap bay.

The stockyard bay, in which the box handling and magnet cranes are to operate, will be situated adjacent to the melting shop, so that the type and amount of material available for charging will always be visible to the melting shop staff, and can be brought to the charging platform immediately it is required. The charging boxes will be loaded on the stockyard floor by means of a 65 in. diameter magnet, and lifted to the charging platform on trays carrying five boxes.

Molten iron will be transferred from the blast furnace plant to the steel plant in 75-ton ladles which will be taken up by the 100 ton cranes serving the charging bay. The hot metal mixer will be of the active type, capable of carrying a maximum weight of 600 tons of molten iron, and will be so designed that the hot metal can be maintained at temperatures approximating to the temperature of the melting furnaces; in this way it will play an important part in the total refining process. The 300 ton tilting furnaces will be charged with hot metal brought from the mixer by the 100 ton cranes, and the appropriate addition of scrap metal will be made by the ground chargers. Both the mixer and open-hearth furnaces will be tilted by electrical means and will be designed for firing by mixed gas and coke oven tar.

Rolling Mill Plant

The rolling mill equipment which is being supplied by Davy & United Engineering Co., Ltd., to meet the requirements of this new works consists essentially of a 42 in. reversing blooming and slabbing mill and a 32 in. reversing three-stand structural mill. Both mills are being designed for a much greater capacity than the 350,000 tons annual output initially required, and will in fact have the capacity to roll up to a million tons a year, against the requirements of the works in what might be termed its intermediate stage of expansion. The electrical equipment is being supplied by The English Electric Co., Ltd.

Blooming and Slabbing Mill.

The blooming and slabbing mill will be capable of rolling slab ingots up to 12 tons in weight into slabs of various sizes, and 4½-5 ton square ingots into blooms down to 6 in. square—the raw material for the 32 in. mill. The working lift of the top roll will be about 58 in. to allow a 56 in. slab ingot to be rolled on edge on the full diameter of the roll. The roll barrels will be 9 ft. long and will be so designed that both slabs and blooms can be produced on the same set of rolls.

The mill will be provided with a 7,000 h.p. 50/120 r.p.m. drive, built as two single armature motors in a twin-drive arrangement in which one motor drives over the top of the other one, via a jack shaft. In this way, the otherwise necessary pinion housing, with its losses and maintenance, is eliminated. The drive will be completed by a motor-generator flywheel set and control gear of the most modern type, giving automatic protection and maximum response rate. The rolls and spindles will be hydraulically balanced from an independent system and fabric linings will be fitted on the roll necks. Two-motor screwdown will be operated by twin 150 h.p. motors, and will give a screwing speed, for the rapid positioning of the top roll, of up to 255 in./min. In line with modern practice, there will be Ward Leonard auxiliary drives for the screwdown, tables and

manipulators. These drives will be fed from motor-generator sets and will be under the control of systems similar to, but simpler than, those for the main drives.

The mill will be fitted with universal manipulators of the electrically operated side guard type for rapid manoeuvring of the ingot before and after each pass through the mill rolls. All manipulator actuating mechanism will be positioned on the main drive side of the mill, thus leaving the opposite side of the mill free for all roll-changing operations, which will be effected by special electrically driven equipment. The manipulator heads on the ingoing side of the mill will be fitted with tilting finger gear for turning over ingots or slabs as required.

Bloom and Slab Shear.

On leaving the 42 in. mill, blooms and slabs will travel forward on driven roller tables to an electric bloom and slab shear which will have a blade load of 1,350 tons. It will be capable of cutting 600 sq. in. of mild steel with a maximum thickness of 16 in., and will be designed to make 9 cuts/min. The shear will be driven by two motors, each of 500/1,000 h.p., through a double reduction gear unit, and control will be provided to give the very rapid acceleration and deceleration needed to allow the sheer mechanism to make only one cut at a time if so required.

Blooms required for subsequent rolling in the section mills will then be given quick reheating treatment in a wash heat furnace, reheating at this stage resulting in better corner filling when section rolling.

Reversing Section Mill.

After reheating, blooms are fed into the 32 in. 3-stand two-high reversing section mill which will be capable of producing structural sections up to 500 mm. joists, rails, billets, rounds and sheet bar in a wide range of sizes. It will be noted that this mill follows the British trend in contrast to the three-high type of mill still common on the Continent and in the U.S.A. for section rolling. The modern reversing mill motor is capable of giving, and sustaining, extremely rapid reversals, sufficient to cope with any rolling programme, and with the two-high design the lifting tables are eliminated, better manipulating and transfer equipment for the product being rolled can be employed, and accurate roll matching is greatly simplified.

Two of the stands will be driven by one 6,700 h.p. 0/80/180 r.p.m. motor with 150 metre-tons working peak and 180 metre-tons cut-out, with an identical motor driving the third stand from the opposite side. These drives will be of the conventional type working through pinions, and again the motors will be complete with motor generator flywheel sets and control gear. The nominal diameter of the rolls is 32 in. with a roll barrel length of 7 ft 6 in. on each stand of the mill. The first two stands will be fitted with electric screwdown gear, and the finishing stand with hand screwdown.

Mechanical manipulators will be fitted to both roughing and finishing stands, the second stand having bobbin tilters for handling billets. Skid transfer gear will operate between all three stands and at both sides of the mill. The run-out roller tables from the second and third stands will be equipped in each case with sliding frame hot saws fitted with stop and measuring gear to facilitate speedy cutting to length of rails and sections before transfer to the cooling banks.

Cold Finishing

The layout of the plant has been designed to give easy and uncongested flow of material, with handling and conveying costs kept to a minimum. At the same time, with an eye to the future, provision has been made for the installation—it may be many years hence—of a second slabbing mill and further secondary mills. An essential feature of the layout of the present scheme is the attention given to the finishing processes, such as

cooling, straightening, cutting to length, etc. Material will be transported by driven roller gear from the cooling banks, through the straighteners, rail enders and drillers, without the use of crane haulage. Provision will also be made in the cooling bank section for the hot cambering of rails, which materially assists the final cold roller straightening operation, since rails which have been hot cambered cool out much straighter, and, thereby, reduce the severity of the cold straightening operation.

Electrical Plant for the Metal Industries Progress in 1952 Reported

CONTINUING our account of interesting electrical plant ordered for or commissioned in the metal industries last year, which commenced in our February issue with brief details of a number of General Electric and British Thomson-Houston installations, reference is made here to the activities in this field of The English Electric Co. Ltd., and Metropolitan-Vickers Electrical Co. Ltd.

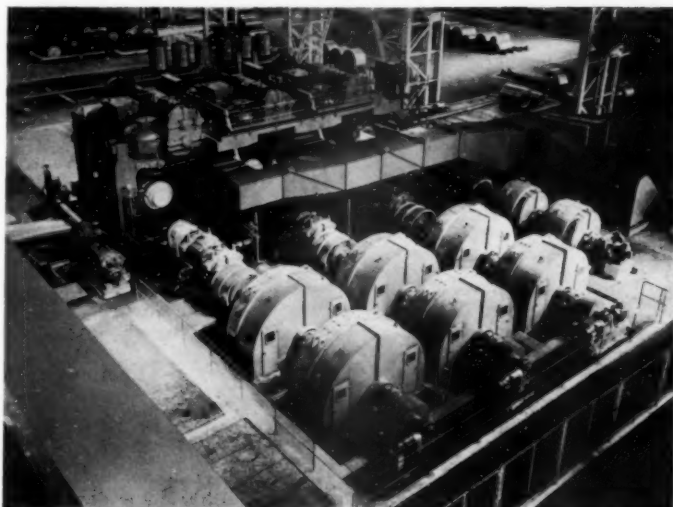
English Electric Co. Ltd.

Rolling Mills.

During the year a considerable number of equipments have been commissioned and interesting orders have been obtained. Those put into service include three for non-ferrous metals and three for ferrous, together with various important auxiliaries. Abroad, a 7,000 h.p. 50/120 r.p.m. blooming mill drive, the second of this rating to be supplied to this particular customer, is now running in Australia, and a slightly smaller blooming mill drive and two associated and similar structural mill drives with all auxiliaries, are now in service in Sweden.

At home, hot mill drives commissioned include those for a continuous copper rod mill and a semi-continuous aluminium mill. The former has four 210 h.p. motors and an 850 kW. grid-controlled rectifier, whilst the latter equipment has two induction motors for roughing and intermediate drives and seven 150 h.p. D.C. motors, with motor generator set, for the finishing train; both equipments were complete with auxiliaries. Cold mill equipments include those for a 1,500 h.p., 1,000 ft./min. 50 in. wide aluminium strip mill with a 300 h.p. coiler, and for stainless steels, a 400 ft./min. reversing Sendzimir mill with a 600 h.p. main motor and two 430 h.p. coiler drives.

Two auxiliary equipments are particularly worth mentioning. Firstly, a slabbing mill on the north-east coast now has a pair of 75 h.p. screwdown motors which will give 150 h.p. each at twice rated voltage and speed, and the necessary motor generator set and control exciters, so that the whole equipment gives maximum response and has maximum self-protection; it is, in fact, the first in service of many really up-to-date hot mill Ward Leonard auxiliary drives already ordered. Secondly, two strip electro-tinning lines in the Steel



The English Electric drive for an 80 in. wide 3-stand tandem cold strip mill, with three 4,000 h.p. D.C. motors and one 1,000 h.p. D.C. motor.

Company of Wales Trostre Works have English Electric transformers and saturable reactors for supplying and adjusting the tin-brightening reflow power, there being in all four transformers and four 835 kVA. saturable reactors.

Delivery is being completed, or commissioning is taking place, on several other equipments, including a 7,000 h.p. 50/120 r.p.m. twin-drive blooming mill equipment abroad and three mills at home, a 14-motor Morgan rod mill equipment with rectifiers in this country, an 8,160 h.p. 50/120 r.p.m. twin-drive blooming/slabbing mill equipment, and a 10-stand Morgan mill equipment totalling 12,500 h.p. and having rectifier supply.

Of the many orders received during the year, it is possible to mention only a few. A 1,880 h.p. hot reversing mill motor has been ordered to replace a motor supplied very many years ago by Siemens, and another replacement order will mean a 750 h.p. slip-ring motor replacing a D.C. motor on an Ilgner set with the displaced D.C. motor being used for driving another mill in the same building.

One large order is for 17 motors with rectifier supply and several auxiliaries for a European rod mill. Another

important order is for main and auxiliary drives totalling over 1,100 h.p. for a Sendzimir planetary hot strip mill, this order being very similar to one secured last year and being the second such equipment ordered in this country.

Six small rolling mill and finishing equipments for Pakistan aggregate 1,200 h.p., whilst numerous other orders relate to equipment for processing such as for cleaning, flattening, trimming and cutting-up and are for delivery both in this country and abroad.

Mercury Arc Rectifiers.

English Electric air-cooled, sealed, steel tank mercury arc rectifiers continue to meet a demand from many different countries, for a simple and reliable design for an increasing diversity of duties. Among the more interesting equipments ordered during the year were two plants for Norway; the first of these includes two 4,800 amp. 750 volt grid-controlled equipments, to extend the aluminium producing capacity of Det Norsk Nitridaktieselskap, while the second includes two 2,000 kW. 600 volt equipments, having grid control for the speed variations of the main drives of a semi-continuous steel mill of the Norsk Jernverk; the latter order also includes three 500 kW. rectifiers for auxiliaries. Other equipments for street traction, steel mills, shipyards, ports, factories, coal mines, etc., have also been ordered.

Miscellaneous.

Welding.—Foremost in the development field is a new type of stepless control of arc welding current by means of ignitrons. It provides a means of controlling on-load current for arc-welding circuits, without resorting to moving core or tapped reactors. The invention is particularly suitable for argon-arc welding but, in addition, it may well find its way into straight A.C. welding, especially in the automatic and heavy current consumable electrode fields.

Switchgear.—Air-blast circuit breakers for operation at various voltages have been supplied, including some at 11 and 22 kV. for arc furnace control duty.

Sintering Plant Fans.—A number of 2,200 h.p.



English Electric slabbing mill motor with an R.M.S. rating of 7,000 h.p. and a speed range of 54/120 r.p.m.

750 r.p.m. salient pole synchronous induction motors, equipped with automatic excitation control, are being manufactured for driving sinter fans in a steelworks.

Electronic Motor Controllers.—A range of electronic controllers has been established to cover D.C. motors from 3 to 100 h.p. for variable speed drive applications. These controllers have been used successfully on a number of applications connected with steel mills.

Induction Heating.—The 10 kW. and 25 kW. heat generators in induction and dielectric versions are being followed by a 50 kW. heater.

Metropolitan-Vickers Electrical Co. Ltd.

Rolling Mills.

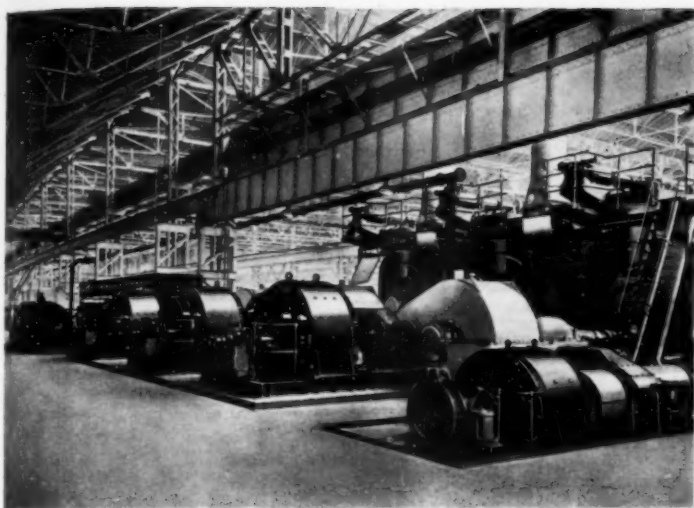
During the year a considerable number of drives have been commissioned, particularly for rolling ferrous and non-ferrous strip. In the largest, an aluminium mill in South Wales, in which slabs are rolled into strip, a reversing mill driven by an 1,800 h.p. 40/52 r.p.m. motor supplied from an Ilgner motor generator set is followed by a three-stand tandem mill having three 1,500 h.p. motors, Ward Leonard controlled. The strip is either coiled on a reel driven by a 400 h.p. D.C. motor, with Metadyne controlled tension, or, for the heavier gauges, fed into an upcoiler with a 75 h.p. D.C. motor. In the same plant, a non-reversing single-stand cold reduction mill is being equipped with a 1,000 h.p. mill motor, a 200 h.p. reel motor and a 50 kW. decoiler motor with tension control.

A number of single-stand reversing strip mills have also been supplied with Ward Leonard drives. These include two 48-in. silicon-steel strip mills, one in South Wales driven by a 2,500 h.p. D.C. motor with two double-armature 1,000 h.p. reel motors, and one in the Midlands with an 800 h.p. main motor and 330 h.p. reel motors. A similar installation in Sheffield for rolling stainless steel strip has a 1,500 h.p. driving motor and 600 h.p. reel motor. All these installations include the Metrovick system of Metadyne and magnetic amplifier control to maintain strip tension.

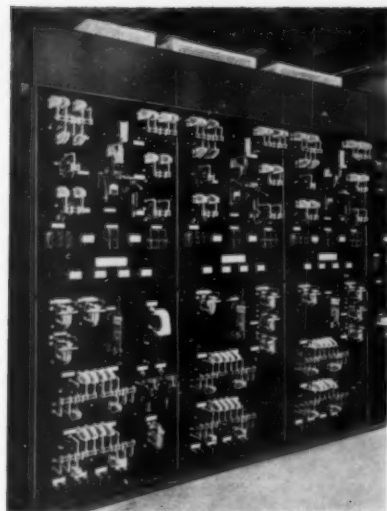
For non-reversing strip mills, two very similar equipments with 1,000 h.p. mill motor, 400 h.p. reel motor and 150 h.p. decoiler motor have been installed in South Wales, one for driving a coil temper mill and the other a coil and combination mill. A further mill of this type, driven by an 800 h.p. D.C. motor supplied from a grid rectifier is rolling non-ferrous material in the Midlands.

A merchant mill of the semi-continuous cross-country type has been commissioned with a 750 h.p. induction motor for cogging, 2,000 h.p. and 2,500 h.p. D.C. motors on 16 in. roughing trains, and 1,500 h.p. and 650 h.p. D.C. motors, respectively, on 16 in. and 10 in. finishing trains. Another three-high merchant mill in the Midlands has been equipped with 600 h.p. and 250 h.p. D.C. motors with flywheels, supplied from motor generator sets, whilst in the Sheffield area, two merchant mills (14 in. and 10 in.) have been equipped with 750 h.p. and 450 h.p. induction motors.

In an advanced state of erection in South Wales is a very large installation including a 4,000 h.p. 50/120 r.p.m. motor driving a 32 in.



A tandem strip mill drive showing the reel motor and three 1,500 h.p. stand motors by Metropolitan-Vickers.



Contact control board for the auxiliary drives of a roughing mill with Ward-Leonard Metadyne control of screwdowns and manipulator head.

reversing mill, Ilgner set and much auxiliary equipment. This mill is followed by a continuous section mill for which auxiliary motors and other equipment is being supplied, a particularly interesting item being an electronically controlled drive for a rotary shear designed to cut billets to very accurate lengths on the fly.

One of the largest synchronous induction motors for rolling mill drives has been delivered to a Scottish steelworks. Rated at 2,000 h.p. 125/187.5 r.p.m. with VAX control, this machine has a rotor diameter of 17½ ft. and is probably the largest two-speed 11 kV synchronous induction motors ever ordered. Several interesting orders are in hand, ranging from duplicate 6,700 h.p. reversing mill Ilgner equipments for the Continent, to a four-high cold mill equipment for experimental strip rolling in Sheffield.

Rolling Mill Auxiliaries.

Two 2,000 ft./min. electrolytic cleaning line drives have been commissioned and, in connection with the 48 in. reversing cold strip mill mentioned earlier, equipment for a 600 ft./min. side trimming and slitting line, and for a 300 ft./min. side trimmer shear and classifier line are under construction. Some of these equipments embody photo-electric loop control.

Electronic control gear has also been developed for use with flying shears. A device for controlling the length of strip cut off employs high-speed counting and batching methods operating on electromagnetically generated pulses, which are produced by the rotation of a measuring roll driven by the strip. The number of pulses is directly proportional to the length of the strip and a pre-set batching control causes the shear to be operated at pre-determined points. An electronic length monitor has been developed to enable billets sheared at speeds of up to 700 ft./min. to be measured accurately on the fly, and two equipments are in course of manufacture. The monitor uses two photo-electric detectors to give pulses, which cause an error indicating instrument to show, in inches, any departure from the correct length. The system will reveal errors of as little

as ¼ in. in 30 ft. with billet speeds from 200 to 700 ft./min. and readings can be taken for individual billets.

An automatic pre-set screwdown control produced for an armour plate mill is capable of being pre-set to $\frac{1}{8}$ in.

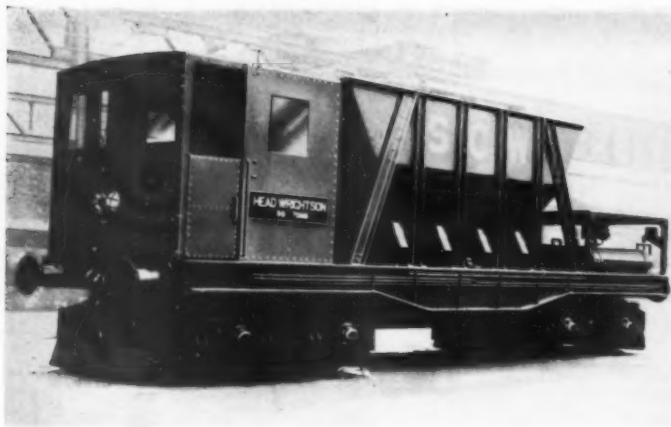
Welding.

Electronically controlled automatic arc welding machines include one supplied to Samuel Fox & Co. Ltd., Sheffield, for the testing of electrode wire, and five to Rubery Owen, Darlaston, for the fabrication of motor car components, whilst numerous sets of electronic control gear have been supplied to firms making their own machines.

On the resistance welding side, a ten-head motor-operated spot welder has been made for welding stainless steel evaporators for refrigerators; it welds 900 spots a minute, the evaporators being fed to the machine by hand. Developments have also continued in seam and projection welders, and a combined projection and spot welder has been developed by fitting the projection machine with spot-welding electrode tips and a foot switch. For atomic hydrogen welding, a triple-arc head has been designed to give higher welding speeds, and a prototype has been made.

Induction Heating.

Amongst the interesting range of high frequency induction heating equipment completed during the year, was an installation for the manufacture of X-ray tube anodes, which was arranged for a continuous sequence of melting, casting and controlled cooling, *in vacuo* or controlled atmosphere as desired. A high temperature vacuum sintering furnace installed in a Government research establishment enables 2,000° C. or over to be attained in a vacuum of 10^{-4} min. Hg. the temperature being closely regulated by a combination of proportional and floating control initiated by a radiation pyrometer of the caesium cell type. The same establishment was supplied with a 10 kW. radio-frequency heating equipment for metallurgical work, and other radio-frequency equipments put into service



Head Wrightson 50-ton steelworks transfer car fitted with Metropolitan-Vickers electrical equipment.

included a 10 kW. unit for brazing the non-ferrous parts of diffusion pumps, and a 20-lb. furnace (35 kW. generator) for melting steel for precision casting.

Miscellaneous.

Transport.—Electrical equipment has been supplied for Head Wrightson Steelworks cars—two 50-ton transfer cars, two 35-ton scale cars and a 60-ton hot-metal ladle car for John Summers new steelworks at Shotton. Equipment has been ordered for a 50-ton

transfer car and a 35-ton scale car for the same user. On the non-ferrous side, the electrification of an ore haulage system covering substation, locomotives, signalling and overhead equipment at the Roan Antelope copper mines, Northern Rhodesia, has been completed.

X-ray Equipment.—An important order for Newton-Victor X-ray equipment covered a million-volt radiographic unit for a government laboratory. Many standard radiographic and crystallographic sets were supplied and in connection with the latter, an automatic shutter that comes into operation on removal of the camera has been developed.

Crack Detectors.—The necessity for the application of magnetic crack detection methods to the inspection of turbine discs and other large components of gas turbines has led to the development of the type T machine, designed for carrying out these tests with the minimum of handling. Also in production is the type Q, with a controllable permanent magnet.

Blast Furnace Auxiliaries.—A fully automatic blast furnace hoist equipment has been put into operation in the Midlands and four more are being manufactured. Thirteen H.V. rectifier equipments are also on order for electrostatic precipitators to be installed at blast furnaces, some of the rectifiers being of the mechanical type and others of the more modern selenium-iron type.

Correspondence

WIRE BILLET SUPPLIES

The Editor,
METALLURGIA.
Sir,

Your assessment of the steel supply position would suggest that the future is bright, and that at the worst there "may be slight shortages in one or two special classes of steel." For the wire trade this, unfortunately, is not in line with the facts, either as regards quantity or quality. At the beginning of 1953 we might well consult a crystal ball to determine the availability of billets against known customer demands, and as far as quality is concerned, we might also be better off buying a "pig in a poke." Although industry as a whole would come to a standstill without wire, it seems to come last in the steel planner's minds.

Statistics are useful, but to the steel-starved wire producer they are rather futile, and on the quality side we are apt, at times, to believe that the whole ingot is now converted without cropping, and that the rose-coloured tonnage spectacles of the inspectors can no longer detect segregation, pipe or surface defects, which are now passed on to the billet roller or rod user for the production of good wire by some miraculous means.

Supply and demand requirements from 1939 to 1952 were tied to severe shortages, sub-standard qualities passing muster in a "take it or leave it" atmosphere, and the habits of over ten years die hard. This phase is now passing, and the customer, quite rightly, wishes to revert at least to the 1939 standard. In one trade alone—welding wire—tonnage lots of 18 in. lengths are sold, and any one length not to analytical requirements

may cause rejection. To meet this, in the absence of a reasonable steel supply, every coil of rod has to be analytically checked prior to conversion—a truly remarkable state of affairs and a poor commentary on the currently available quality of steel. For rope wire and similar trades, every rod of some casts has to be checked for segregation to avoid processing materials which will give low efficiency in the wire mills, and which cannot be used in mining ropes or high quality springs or tyre cord.

As an industry, the wire trade is to-day being squeezed between the millstones of shortages and poor quality as far as the steel maker is concerned on the one hand, and the rightful customer demand for quality and quantity on the other. As a technologist concerned solely with wire production, I would suggest all is not well with steel for this key industry. Quality is needed with ample tonnage, not only for the home market converter, but also for the export market, which is being severely hampered by the current and forward position of billet supplies.

I would make it clear that the above comments are my personal views, and are not necessarily those of my company.

Yours faithfully,
C. F. BRERETON.

Manchester.
24th February, 1953.

INCREASED sales and service activities have led to the opening of a new branch office by Messrs. Honeywell-Brown, Ltd. at 67, Exchange Buildings, Stephenson Place, Birmingham, 2. (Telephone: MID 0857).

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Fig.

Vertical Furnace for Enamelling

THE advantages of using continuous furnaces for operations involving heating and cooling, through the same range of temperature, of large numbers of articles are well known, and the method has been widely employed in the field of vitreous enamelling. A recent continental installation incorporates two tower-type furnaces which open up new possibilities for smaller concerns with a wide range of enamelling work, and for large factories, equipped with continuous enamelling furnaces, where it is necessary to carry out smaller orders of varying sizes.

The furnace used is a continuous and reversible tower-type furnace, designed and built by Messrs. Gebr. Ruhstrat, Göttingen, which requires little floor space and is suitable for a wide range of articles of different sizes. Its throughput is high, and it can readily be adapted to the changing conditions and requirements of normal practice.

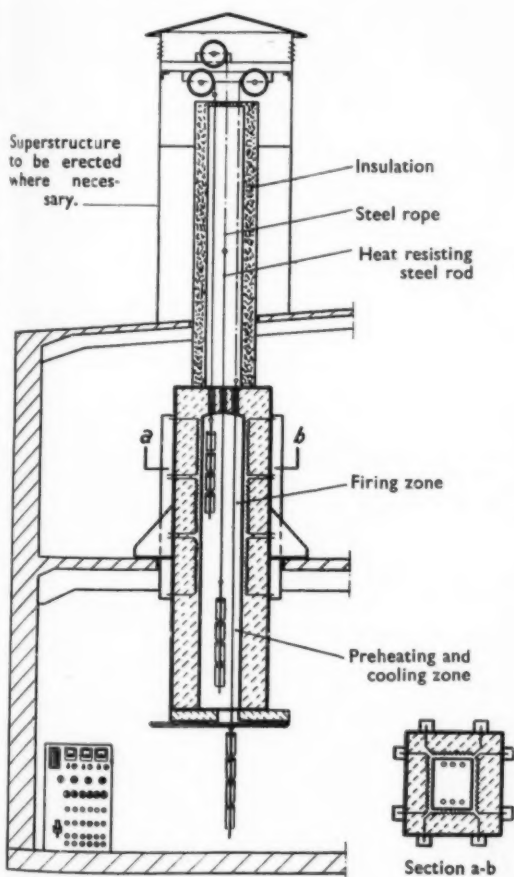


Fig. 2.—Section through a tower-type enamelling furnace installation.

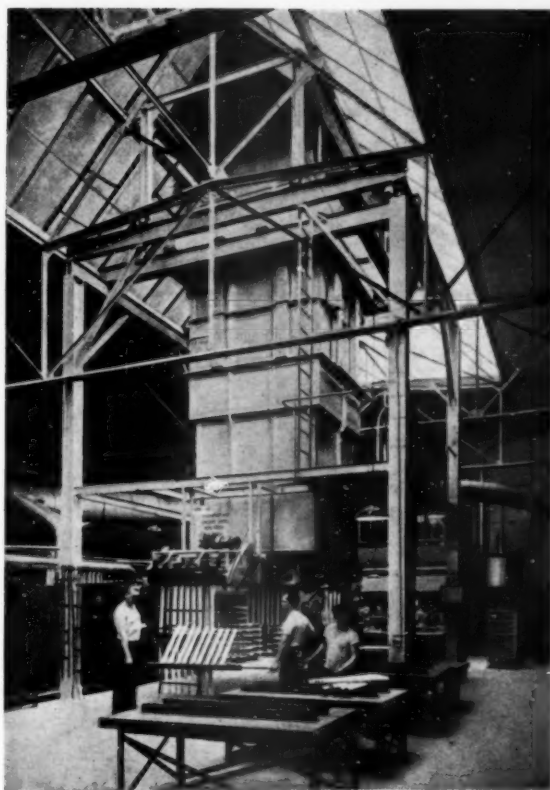


Fig. 1.—General view of the Gebr. Ruhstrat enamelling furnace.

A section through the furnace is shown in Fig. 2, from which it will be seen that the flow of work to be enamelled is vertical. The articles are attached to vertical lightweight racks which are suspended by steel wire ropes from drums at the top of the furnace tower. Each drum is driven by a separate motor fitted with automatic reversing gear, and by this means the work is raised through the preheating zone to the firing zone until the motor reverses, lowering it slowly through the combined preheating and cooling zone, where some of its heat is transferred to incoming work attached to one of the other drums. The furnace has, therefore, the advantages that the material is slowly preheated and cooled, thus minimising distortion, and that the fuel consumption is low, advantages which it shares with the large continuous conveyor type units. The temperature range of the furnace extends to 1,000° C., heating being effected by easily replaceable electric resistors, and the temperature can be pre-set and automatically controlled.

Several racks with independent drum gear can be accommodated in each furnace unit and in this way a high throughput is attained because the furnace is always loaded with material. When enamelling articles of small or medium dimensions, all the available furnace trays and their suspension gear are used, but for enamelling work of exceptionally large dimensions only one or two racks are in use. This arrangement makes the furnace readily adaptable for dealing with throughputs of varying sizes.

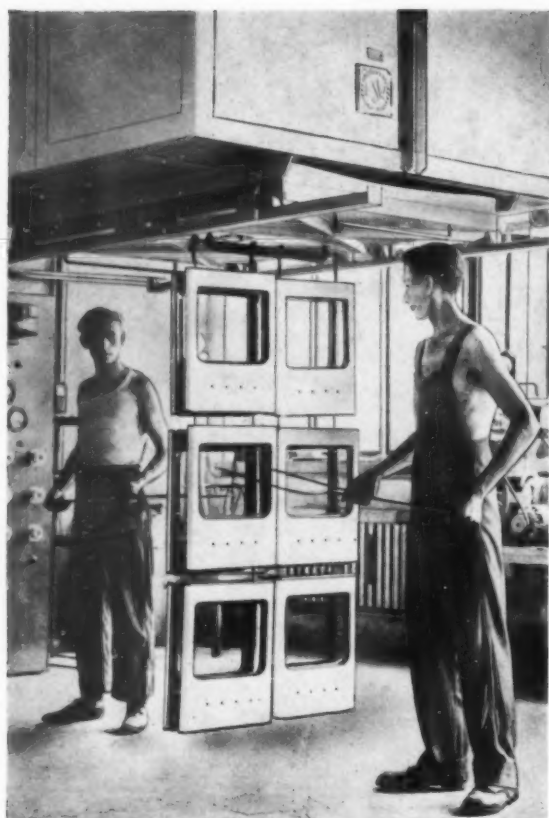


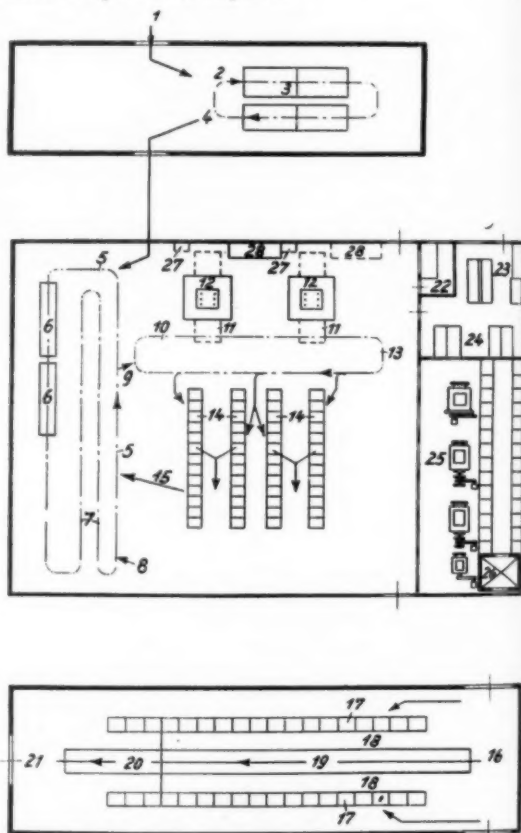
Fig. 3.—Loading the furnace racks.

Furnaces of the dimensions shown in Table I have been standardised and it will be seen from this and from Fig. 1, that very little floor space is taken up by these units. Other advantages include the following: it is easy to enamel articles of varying size and weight at the same time, and to alter the load without any inconvenient change of routine; the operators are not exposed to heat; any scale formed drops on to the furnace floor; the fuel consumption is low. In illustration of the last point some particulars can be given concerning a furnace of 2 ft. 7½ in. × 2 ft. 3 in. section. When charged with ⅛ in. thick parts of gas or electric stoves, it has a throughput of 8 cwt./hr., with a power consumption of 225 kWh./ton, whilst when charged with 2½ gallon buckets, the throughput is 5½ cwt./hr. and the power consumption 290 kWh./ton. 20 gauge thick front covers of electric stoves can be dealt with at a rate of 7 cwt./hr. and a power consumption of 235 kWh./ton.

TABLE I.—STANDARD FURNACE DIMENSIONS.

Internal Furnace Section	21½ in. × 31½ in.	31½ in. × 39½ in.	39½ in. × 47½ in.
Height of Heating Zone ..	4 ft. 1 in.	7 ft. 3 in.	8 ft. 3 in.
External Dimensions—			
Width	4 ft. 6 in.	5 ft. 11 in.	8 ft. 3 in.
Length	5 ft. 3 in.	6 ft. 7 in.	8 ft. 10 in.
Height	13 ft. 6 in.	19 ft. 0 in.	21 ft. 4 in.
Maximum Temperature ..	1,000° C.	1,000° C.	1,000° C.
kW. Rating	80	150	200

In Fig. 3 can be seen the charge and discharge end of the furnace and the room for handling, while Fig. 4 shows a typical layout of a modern continuous enamelling plant incorporating two Ruhrstahl tower furnaces and having a throughput of 1 ton/hr. for single fired ware. The material arriving from the die presses on a chain conveyor is brought to the pickling and rinsing plant, and from there it is taken by a continuous conveyor to the automatic spraying booth, being dried on the conveyor track. Alternatively, it can be dipped by mechanical means and dried in a drying furnace. After cleaning and checking the work is suspended on the vertical racks and passed through the furnace. Other combinations for ground and cover firing can easily be arranged. Finally, a further conveyor removes the enamelled ware to the stores or to the assembly shop, where the parts are required.



(1) Arrival of material from die-presses. (2) Chain conveyor. (3) Pickling plant. (4) Discharge station for pickled material. (5) Suspended chain conveyor I. (6) Spraying booths—(a) booth for ground enamel; (b) ditto for cover enamel. (7) Drying conveyor. (8) Cleaning and checking stations. (9) Loading and unloading station. (10) Chain conveyor II. (11) Charge and discharge gear. (12) Tower enamelling furnaces. (13) Check point. (14) Store for partially finished goods. (15) Charge gear for partially finished goods. (16) Assembly shop. (17) Stores. (18) Assembly bench. (19) Assembly conveyor. (20) Testing bench. (21) Despatch bay. (22) Offices. (23) Laboratory. (24) Desks. (25) Grinding mill room, one grinding mill for 1/2 ton ground enamel, two ditto each for 4 cwt. white covering enamel, one trial mill for 1/2 cwt. (26) Elevator. (27) and (28) Switches and control gear for enamelling furnaces.

Fig. 4.—Layout of continuous enamelling plant incorporating two tower-type furnaces.

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"It makes me hopping mad," complained the Cat on Hot Bricks,
"when they can't even keep the temperature constant from one minute to the next. What's wrong with this firm? They ought to use oil fuel." All they've got to do is to contact Shell-Mex and B.P. Ltd., and get the best advice on controlled heat that anyone could come across in nine lifetimes."



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NEWS AND ANNOUNCEMENTS

Institute of Metals Awards

W. H. A. Robertson Medal and Premium. The Council of the Institute of Metals has awarded the 1952 W. H. A. Robertson Medal and a Premium of 50 guineas to Mr. J. F. WRIGHT, Engineer, West Midlands Gas Board, for his paper on "Gas Equipment for the Thermal Treatment of Non-Ferrous Metals and Alloys," published in the *Journal of the Institute of Metals*, 1952, vol. 80, pp. 269-285. The Medal and Premium of 50 guineas, placed at the Council's disposal by W. H. A. Robertson & Co., Ltd., is awarded annually for the encouragement of the writing and publication in the Institute's "Journal" of papers on engineering aspects of non-ferrous metallurgy. Manuscript of such papers should be addressed, in the normal way, to The Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1.

Students' Essay Prize Competition, 1952. The Council had made two awards, of 10 guineas each, for essays submitted in connection with the Institute's annual Student's Essay Prize Competition. The awards are to Mr. R. D. STACEY, of the University of Birmingham, for an essay on "Some Experimental Evidence for Dislocations"; and Mr. G. THOMAS, B.Sc., of Cambridge University, for an essay on "Martensitic Transformations in Non-Ferrous Metals and Alloys." Both are Student Members of the Institute.

Fifth International Mechanical Engineering Congress

THE Fifth International Mechanical Engineering Congress will be held in Turin, Italy, from October 9th to 15th, 1953, during the Salone Internazionale della Tecnica, so that participants can visit this important exhibition. The organisation of the Congress will be in the hands of the Associazione Industriali Metallurgici Meccanici Affini of Italy, with the support of the Organising Committee, the members of which are also the Mechanical Engineering Trade Associations of Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Holland, Luxembourg, Norway, Spain, Sweden and Switzerland.

The theme of this year's Congress is "Production and Assembly Methods for Components in Mechanical Engineering," the subject being covered both from the technical point of view and from the stand-point of production costs. In view of the wide scope of this theme, it is not intended to consider raw materials, measurements, inspection, tests or erection, but to concentrate on:

- (a) the technology of manufacture with or without chips (machining; grinding; oxy-acetylene cutting or erosion; various foundry methods, including precision casting; forging; punching; drawing; powder metallurgy, etc.);
- (b) various methods of assembly (welding; brazing; riveting; expansion-fitting and ferruling; bonding; key fixing; clamping; screw and bolt fitting, etc.); and
- (c) comparative studies on the different techniques.

During the period of the Congress, participants will have the opportunity of visiting a number of industrial

establishments in and around Turin, and a study-tour has been arranged for the week following the Congress when visits will be made to large industrial undertakings in Central Italy.

Further particulars can be obtained from The British Engineers' Association, 32, Victoria Street, London, S.W.1.

Mond Nickel Fellowships

THE Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for 1953. The main object of these Fellowships is to enable selected applicants of British nationality and educated to University degree or equivalent standard to obtain additional training and wider experience in industrial establishments, at home or abroad; so that, if they are subsequently employed in executive or administrative positions in the British metallurgical industries, they will be better qualified to appreciate the technological significance of research and to apply its results.

There are no age limits, though awards will seldom be made to persons over 35 years of age. Each Fellowship will occupy one full working year. It is hoped to award five Fellowships each year of an approximate value of £900 to £1,200 each.

Applicants will be required to define the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications and previous career. Full particulars and forms of application can be obtained from: The Secretary, Mond Nickel Fellowships Committee, 4, Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the Committee not later than June 1st, 1953.

Factory Equipment Exhibition

THE forthcoming National Factory Equipment Exhibition at the Royal Horticultural Hall, London, will be the first of its type to be held in Europe. Great interest has been aroused among manufacturers of equipment of all kinds used in factories and offices, and one of Britain's leading industrialists, Sir Miles Thomas, will open the exhibition on March 23rd. Sir Miles Thomas is well-known as Chairman of B.O.A.C. and past President of the Society of Motor Manufacturers and of the Advertising Association. H.R.H. The Duke of Edinburgh has promised to visit the exhibition on the second of the five days it will be open.

The principal object in holding the show is to stimulate the interest of directors, works and factory managers, and those concerned with the control of factories or works departments, in modern equipment designed to increase efficiency and achieve economy in industrial activity, and contribute to the safety and welfare of workers. So far, exhibits which have been booked to appear include mechanical handling equipment, costing and accounting systems, safety equipment including protective clothing of all types, automatic tools, dust removal systems, factory maintenance systems and layouts, and workers' welfare equipment.

The Institution of Metallurgists

1953 Examinations

THE next Examinations for the Licentiate and Associateship of The Institution of Metallurgists will be held from August 24th to September 1st, 1953. Candidates must submit their applications for permission to enter the examinations before May 1st. Each application must be made on a form to be obtained from the Registrar-Secretary, The Institution of Metallurgists, 4, Grosvenor Gardens, London, S.W.1, and must be accompanied by a registration fee of one guinea, the balance of the examination fee being payable before August 1st. Examinations for the Fellowship will be held at the same time and intending candidates should apply for permission to enter, submitting, for the approval of the Council, a statement of the subject of the dissertation or the branch of metallurgy in which they offer themselves for examination.

Further particulars can be obtained from the Registrar-Secretary, as can copies of the papers set at the examinations held in the years 1947-1952, at a cost of 1s. per set.

World's Biggest Blast Furnace Ordered

PRECISELY 25 years after the setting up by Ashmore, Benson, Pease & Co., Ltd., of the Blast Furnace Division, under the management of Major W. R. Brown, D.S.O., now Senior Director of the Company, an order was received recently from the Steel Company of Wales for the construction of the largest blast furnace built anywhere in the world. No more than ten years ago, the idea of building such a furnace outside the United States, which has a total output of iron some five times that of this country, would have been regarded as fantastic. That the industry is prepared to embark upon such a project is a tribute to the courage of its leaders.

During the last ten years, 20 blast furnaces have been ordered from Ashmore, Benson, Pease, and of these, 13 are already producing 3,500,000 tons of pig iron annually for the enrichment of the British Empire, while the remaining seven, destined for British works, will add a further 2,000,000 tons of iron each year to meet the needs of modern industry. The orders in hand for blast furnaces and ancillary equipment total nearly £10,000,000 and will provide a large volume of work for the firm's workshops. To meet this anticipated increase, the fabricating facilities were greatly expanded with the construction of the new South Works in 1951.

Institute of Metal Finishing

Organic Finishing Group

As announced in an earlier issue, the Inaugural Meeting of the newly-formed Organic Finishing Group of the Institute of Metal Finishing will be held at the Charing Cross Hotel on Thursday, March 19th, 1953. A short business meeting at 2.30 p.m., the main purpose of which is to elect the Committee which is to organise the first year of the Group's activities, will be followed by a technical session at which two papers will be presented for discussion. They are: "Problems of Paint Application," by Mr. A. A. B. Harvey (Messrs. Briggs Motor Bodies, Ltd.); and "Problems of Dip and Spray Painting," by Mr. D. H. Lloyd (Messrs. Fisher & Ludlow, Ltd.).

Personal News

MR. M. W. THRING has been appointed an Assistant Director of Research of the British Iron and Steel Research Association. He will continue as Head of the Association's Physics Department.

THE appointments are announced by The General Electric Co., Ltd., of Mr. F. R. LIVOCK as Controller, Education and Personnel Services; and of Mr. G. B. L. CHIVERS as Staff Manager of the Sales Organisation.

MR. H. E. CLIVE, O.B.E., and MR. J. T. SMITH, retired recently from the Board of the Metals Division of Imperial Chemical Industries, Ltd., after 42 and 30 years service with the Company and its predecessors.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announces that MR. C. H. FLURSCHHEIM, Chief Engineer, Switchgear Department, has been appointed Assistant Chief Electrical Engineer in addition to his present duties.

MR. P. B. HIGGINS has been appointed to the Board of Specialoid, Ltd.; MR. R. H. MAINSWORTH, Director and General Manager, is now Managing Director, and MR. T. O. HUNT, Chief Designer and Technical Manager, has become Technical Director.

MR. J. D. DUNLOP, M.C., Works Manager of the Lancashire and Corby Steel Manufacturing Co., Ltd., is to join the technical sales staff of Sir W. G. Armstrong Whitworth & Co. (Ironfounders), Ltd., and will be attached to the office at 6, St. Alban's Street, London, S.W.1.

MR. IVAN STEDEFORD, Chairman of Tube Investments, Ltd., recently visited South Africa for consultations with associate and subsidiary companies, and to observe at first hand general industrial trends in the Union. During his stay, he also visited Rhodesia.

MR. A. HORNER, Director and General Manager of Darlington & Simpson Rolling Mills, Ltd., has been appointed Managing Director.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announces that MR. H. S. CARTER has been appointed Sales Manager, Heating and Welding Department, which has been formed to co-ordinate the sales of heating elements—including radiant boiling plates and infra-red equipment—radio frequency heaters, induction furnaces, welding equipment and electrodes.

Obituary

WE regret to record the deaths of the following:

MR. A. P. GOOD, Deputy-Chairman of the Brush Aboe Group of Companies, who died in South Africa on February 10th, at the age of 46, after a long illness.

MR. J. TAYLOR, of the Patent Die Casting Co., Ltd., who died in London, on February 12th. Mr. Taylor was one of the founder members of the Zinc Alloy Die Casters' Association, and a member of Council since its formation in 1942.

MR. ERNEST B. HALL, Chairman and Governing Director of Hall & Pickles, Ltd., who died on February 11th. Mr. Hall was an adviser to the Iron and Steel Control during the war.

MR. DOUGLAS JEPSON, Head of the Metallurgy Department of the College of Technology, Birmingham, who died on February 24th, after a brief illness.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Gang Slitting Machine

BUILT to give absolute precision in operation, the Besco Production Model No. 36 Gang Slitter embodies the essential modern features, necessary to mass production technique, of faster and more efficient feeding, with accurate cutter maintenance. The machine has been designed with practical forethought for introduction into existing production lines and the grinding attachment, cutters and hubs are interchangeable in some cases with similar equipment produced by other well known machinery manufacturers.

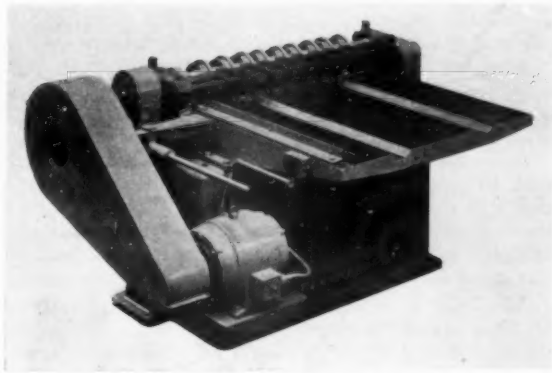
Simple to operate, this machine can handle sheets up to 36 in. wide, and will slit lithographed and other tin plate, with accurate parallel cuts, up to 60 sheets per minute, according to the operator's skill. Its speedy performance and ease of adaptability for the cutting of blanks for all kinds of metal packs makes it eminently suitable for installation in can making lines where frequent changes in size are required. Mild steel sheet up to a maximum thickness of 0.0375 in. can also be cut with fewer cuts per operation.

Constructed to endure long working periods at high output rates, the machine is manufactured with the table, a heavily ribbed casting with a precisely machined flat top surface, superimposed upon a rigid box section cast iron stand of ample strength for complete steadiness while running. The machine is arranged so that it can be driven by belt from a line shaft or by a self-contained motor with drive and machine cut gears adequately guarded by sheet metal covers. All working parts, drive gears, clutch, etc., with the exception of the gears for driving the feed-in rolls are positioned on the left hand side of the machine.

The shearing cutters are of high grade alloy steel, with double edges, ground with uniform accuracy, to an angle of $1\frac{1}{2}^{\circ}$ to 3° , from the outside edge towards the centre, the variation of grinding angle depending upon the hardness of the material which is to be cut. These cutters are attached by countersunk screws to the hub, this being locked on the shaft by a method which ensures long cutter life and accurate cutting. Should one side of the cutters become dull they can be mated with either the inside or outside cutting edge, thus providing a double life for each cutter and a ready answer should one edge become dull.

An electrical grinding attachment can be supplied, and this may be said to be essential equipment because the cutters must be ground with uniform accuracy and this can only be achieved on the machine. The grinding apparatus fits to the rear of the machine, after removal of the feed-out rolls, and the grinding of the cutters takes place *in situ*.

Feed rolls, for fixing in front of the cutters, can be supplied if required. These are a special feature of the machine and greatly increase feeding efficiency in slitting, preventing twisting of the metal during cutting operations, particularly while cutting very narrow strips. Guide fingers, with finger bars can be supplied, for supporting the metal in position while slitting.



These are not necessary if front rolls are used. Feed out rolls are fitted to the rear of the machine and easy access is provided to the fixing screws of the bearings when the necessity of grinding the cutters makes removal of the rolls essential. All rolls are of high grade alloy steel, heat treated and precision ground, and ample means of lubrication are provided.

F. J. Edwards Ltd., 359-361, Euston Road, London, N.W.1.

Non-Photographic Filters

FOR more than 40 years, Wratten Light Filters have been supplied by Kodak, Ltd., for various scientific purposes. Chief of these has been in connection with photography, and the filters have, therefore, normally been catalogued from the point of view of the photographer. Photographers and users of photographic techniques are not alone in their need for reliable light filters, however, and Kodak technicians have, during the past two or three years, devised new methods for the production of filters designed to cater for the specific needs of customers in terms of spectral transmission, size and finish. These Non-Photographic Filters can be supplied for use in laboratory instruments such as photo-electric absorptimeters, colorimeters and other scientific apparatus, or for work of a much less accurate nature.

Basically, these filters consist of a sheet of glass coated with a dyed gelatine layer, and can be supplied cut into squares or circles, and, if required, cover glasses can be bound on to them with good quality self-adhesive binding tape. When filters are required to withstand temperature or atmospheric changes, or are likely to be subjected to handling, they can be protected with a cemented cover glass, the special heat-resisting plastic cement used being suitable for withstanding temperatures up to 60°C .

Kodak Non-Photographic Filters are only produced in response to special demands, and are not normally held in stock, their supply being arranged as a result of negotiations between customer and maker. Occasionally a little stock remains when an order has been completed.

Kodak, Ltd., Industrial Sales Division, Kodak House, Kingsway, London, W.C.2.

Temperature Indicating Paints and Crayons

THE B.A.S.F. Thermocolour temperature indicating materials are colours which have the characteristic property of changing when certain temperatures are exceeded. Increases in temperature do not cause merely slight alterations in shade of the original colour, a distinctly visible colour change takes place, and as the changed colours normally do not recede on cooling, observations may be made at any time after the conclusion of the temperature rise. Some of the Thermocolours undergo one colour change whereas others undergo successive ones.

The colour powders are applied in the form of a paint with industrial methylated spirit, and 1 lb. of colour is sufficient for 5-7½ sq. yd. of surface. The adhesion of the coat is in itself satisfactory, but if particularly good adhesion is desired it can be obtained by the addition of a special binding agent.

Because of their nature, Thermocolour brands in general cannot be used under water or in steam, and certain gases affect some of the colours. Atmospheric moisture causes the changed colours of certain grades to recede gradually. If these particular colours are damped, the colour recedes rapidly and the original colours reappear; they can then be used again for indicating temperatures.

Further additions to the range of temperature indicating products are the A. W. Faber Thermochrom Crayons. These embrace a temperature range from 65° to 670° C. and their handy form, packed in boxes of 12 or 15, make them convenient for carrying around during the day's work in the factory or laboratory.

Allied Colloids (Bradford) Ltd., 11, Great St. Thomas Apostle, Queen Street, London, E.C.4.

Vacuum Gauge

THE type 511 Alphatron* Vacuum Gauge is a refinement of earlier models which for the past eight years have established a reputation for accurate, dependable performance in laboratory, pilot plant, and industrial uses. The principle of operation is related to the conventional hot filament ionisation gauge, with the important difference that the Alphatron gauge employs a shielded radioactive source instead of a hot filament. Alpha particles ionise the gas, and the ionisation current produced is measured by a D.C. amplifier which

* Registered Trade Mark.



is calibrated to give absolute pressure in millimeters of mercury.

The sensing element and first stage amplifier are housed in a steel envelope which weighs only four ounces. Attachment to the vacuum system is made by a ⅛ in. standard pipe thread tubulation. The power supply, high stage amplifier, range selector, and output meter are incorporated in a compact stainless steel housing weighing seven pounds. Dependence on outside power supply which is subject to fluctuation is eliminated by the use of readily available batteries. The use of batteries also eliminates an expensive regulated direct current power supply and substantially reduces the cost of the gauge.

Among the improvements which have been incorporated in the new unit is a greatly increased range. Linear indications of total pressure are provided between 1,000 millimeters and 10⁻⁴ millimeters by ranges as follows:—

Range	Smallest Division	Range	Smallest Division
0-1,000 mm.	0-1 mm.	10 mm.	0-01 mm.
0-100 mm.	0-0-1 mm.	1 mm.	0-001 mm.
0-10 mm.	0-1-01 mm.	0-1 mm.	0-0001 mm.

Accuracy is $\pm 2\%$ of full scale. Speed of response to pressure changes is instantaneous, making the gauge useful also as a leak detector. The Alphatron ionisation chamber is far less sensitive to contamination than hot filament or thermo-conductivity types of gauge chambers and, when heavy contamination resulting from unusual operating conditions does occur, cleaning is accomplished simply by flushing with a suitable solvent.

Type 511 Alphatron gauge is particularly useful on vacuum coating units, furnaces, stills, drying and impregnating units, test chambers, and pumping systems; it is equally versatile as a laboratory instrument.

National Research Corporation, Seventy Memorial Drive, Cambridge, Massachusetts, U.S.A.

Three-Phase Balancer

CERTAIN types of electrical apparatus, such as resistance welders, are welders, furnaces, etc., are only suitable for use on two of the usual three-phase supply wires, which is a matter of concern to electric supply authorities and works engineers. Various attempts have been made to solve the problem, and a simple device has recently been designed, the S.R.W. balancer unit, which, under the most exacting tests, has proved its ability to give an equally balanced load on all three phases, and a high degree of power factor correction.

The load balancer unit made by Standard Resistance Welders, Ltd., is of neat and compact design, and consists of a combination of small reactors, chokes and condenser units, assembled in a robust fabricated frame which also houses the contactor. All parts are accessible and its outstanding features are that it cannot be overloaded, it has no moving parts, and it requires no maintenance. Other notable points are that the heat control at the welding electrodes is infinitely variable and automatic, thus no tappings on the machine transformer are necessary. The unit can be designed for use on any multi-phase system and voltages, and it can be installed in a position remote from the welder.

Standard Resistance Welders Limited, Mucklow Hill, Halesowen, Near Birmingham.

CURRENT LITERATURE

Book Reviews

MAN AND THE CHEMICAL ELEMENTS FROM STONE-AGE HEARTH TO CYCLOTRON

By J. Newton Friend. 354 pp. including indices. London, 1951. Charles Griffin & Co., Ltd. 27s. 6d. net.

DR. NEWTON FRIEND is already justly famed as a technical writer possessing a pleasing style happily blended with wide erudition; the present volume is readable, instructive and entertaining and contains not only standard textbook chemistry (presented in a most original manner) but also much collateral information which cannot fail to grip the imagination of the chemist or metallurgist interested in the development of his science.

The author is particularly concerned with the history of the extraction, identification and classification of the elements and in gathering information has cast his net widely as the copious references to astonishingly varied sources will bear witness. The grouping of the elements is sometimes unorthodox and to be commended in a work of this nature. Thus oxygen, nitrogen and hydrogen are classed together as "The Permanent Gases" and mercury is treated with lead and tin ("The Heavy Metals").

The story of each element unfolds itself in dramatic fashion with a wealth of interesting and occasionally amusing anecdote; in discussing elements, and particularly metals, known to the ancients, much data has been drawn from Biblical and Egyptian sources. In the final section of the chapter on carbon the reader is treated to a concise history of the more famous diamonds, of which the ill-starred Hope diamond is perhaps the best known.

The title of the book might suggest a general survey designed primarily for the enquiring layman; it may well be that non-technical readers could derive considerable instruction and entertainment from a study of these pages, but in the opinion of the reviewer this work should be regarded as an historical study calculated to refresh the memory and stimulate the enthusiasm of the trained scientific worker.

Most students will, on occasion, have paused for a while in their study of the facts and theories of their subject to ponder on the habits and characters of the early workers who laid the foundations of the complicated scientific edifice which stands so firmly to-day. The names of Berzelius, Davy, Bunsen and other pioneers frequently recur and many obscure details relating to their lives and work are introduced into the main theme without any sense of irrelevance. Thus these great names are more easily associated in the mind with real people when we read of Wohler temporarily suspending his investigation of vanadinite (owing to a temporary indisposition consequent on the inhalation of hydrofluoric acid vapour) and losing, as a result, priority in the discovery of vanadium. Other references which possess a similar human quality may be cited; for example the merchant Brand, who discovered phosphorus in urine (when looking for gold and so indirectly achieving his aim) and used to hide in the Hartz mountains lest his secret should be discovered, and

Count Rumford who took for wife the widow of the executed Lavoisier.

Dr. Friend indulges in a number of major digressions from the main theme which go to enhance the general appeal; in discussing the uses of mercury, several pages are devoted to the development of the thermometer and the various scales of temperature, and in the section on hydrogen there is included an account of the development of the balloon from the time when Joseph Black mystified his friends by exhibiting an inflated calf's bladder which rose unaided to the ceiling.

It would be churlish to make petty criticisms of what is an admirable study of a very wide field but it should be mentioned that magnesium base alloys (p. 152) rarely, if ever nowadays, contain copper as an alloying element (in fact copper is regarded as a dangerous impurity) and the use of cadmium base alloys is so restricted by the scarcity and cost of the metal that their application in automobile fittings is certainly not common (p. 159).

The final section of the book is devoted, most appropriately, to a brief survey of the radioactive elements and the methods used in the preparation of the transuranic elements.

C. J. BUSHROD.

SPECTROGRAPHIC ANALYSIS OF LOW-ALLOY STEELS

A report of the British Iron and Steel Research Association published as Iron and Steel Institute Special Report No. 47. 83 pp. 18 illustrations. Cloth boards. Price 15s. (7s. 6d. to members of the Institute).

THE variations in spectrographic technique employed in different laboratories for the analysis of iron and steel have been examined by the Spectrographic Analysis Sub-Committee of the British Iron and Steel Research Association. Based on the most successful of the alternative procedures examined, a recommended method for the spectrographic analysis of low-alloy steels has been drawn up and given extensive trials on a series of chemically analysed standards, with very satisfactory results. A description of this method, which uses a large dispersion quartz prism instrument with a condensed spark discharge for excitation of the samples, forms the last part of this book.

The method is applicable to the analysis of low-alloy steels with an iron content of $95\% \pm 1\%$; for compositions outside this range a correction is necessary. The elements which may be determined and the concentration ranges covered are:—

Element	Concentration Range, %
Silicon	0.05-0.80
Manganese	0.05-1.50
Nickel	0.10-5.00
Chromium	0.05-3.00
Molybdenum	0.05-1.50
Vanadium	0.03-0.65
Copper	0.05-0.50

Recommended line pairs are given for each element. Standard deviations are given for various concentrations within these ranges and show good reproducibility which, the report states, was not improved by the use of controlled sources of excitation.

The first part of the book presents the information upon which the standard method was based, giving in some cases alternative procedures or accessories while theoretical considerations and detailed operating instructions are included where necessary. The chapter headings in this part of the book are: The Spectrograph, Electrodes, Excitation Sources, Photographic Plates and Processing, Plate Calibration, Photometry, Spectral Line Pairs, Direct Reading.

Trade Publications

A GOOD deal has been learnt of the behaviour of aluminium paints in all conditions of exposure since the publication of "Noral Paste for Paint," and there have been considerable advances in formulation and manufacture. In the latest Northern Aluminium book "Alpaste," which is addressed to the user as well as to the paint technologist, there is, therefore, much that is new. It contains chapters on manufacture, properties, and methods of application to a wide variety of surfaces, and a special study is made of printing with aluminium inks, subjects discussed including both æsthetic and practical aspects of the design of matter to be printed, papers to be used, formulation of inks, and the technique to be adopted in the actual printing. Copies may be obtained from Northern Aluminium Co., Ltd., Banbury, Oxfordshire.

THE Aluminium Development Association Directory of Members gives the names of Members of Council, a brief statement of the constitution and objects of the Association, and the names, addresses and other particulars of its Member Companies, including, where applicable, associate or subsidiary companies. In each case, a short description is given of the activities and products of the company. By means of a classified index, readers are referred to all Member Companies producing a particular product.

CRUCIBLE furnaces of various types and capacities are featured in a series of leaflets issued recently by The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11. The first concerns central axis tilting furnaces which can be supplied for oil or gas firing; except for the smaller sizes, power tilting is available if required. The type LO oil-or-gas-fired lift out crucible furnaces detailed in the second leaflet have been designed to meet the need for a general purpose melting unit to handle a variety of small charges in the foundry with the maximum efficiency and economy. Lastly, there are the bale-out crucible furnaces designed and engineered specifically for the die casting industry. These furnaces are available for oil, gas or coke firing.

B.A. ALUMINIUM PASTE is the subject of a new publication of The British Aluminium Co., Ltd., Norfolk House, St. James's Square, London, S.W.1. Aluminium pigment in the form of dry flake powder has been in commercial production for over fifty years, but it is only during the last twenty years that the paste form has become available. Its outstanding advantage over flake powder has no doubt been responsible for the increased popularity of aluminium paint. The publication opens with a discussion of the general characteristics of aluminium paint which are of particular value in the surface protection of metal, wood, brick, plaster, concrete, etc., and includes illustrations of the wide range of uses for

aluminium paint. Information follows on types of aluminium paint, recommended painting technique, and the properties, storage, and testing of aluminium paste.

Books Received

"Ferrous Analysis—Modern Practice and Theory." Second edition revised. By E. C. Pigott. 690 pp. inc. appendices, index and 65 illustrations. London, 1953. Chapman & Hall, Ltd. 84s. net.

"Hydrometallurgy of Base Metals." By George D. Van Arsdale. Prepared with the assistance of the Dorr Company Staff. 370 pp. New York, Toronto and London, 1953. McGraw-Hill Book Co., Inc. \$9.50 or 81s.

"Industrial Brazing." By H. R. Brooker and E. V. Beatson. 344 pp. inc. 203 diagrams and photographs and 32 tables. Published for "Welding and Metal Fabrication." London, 1953. Iliffe & Sons, Ltd. 35s. net.

"The Welding of Austenitic Corrosion- and Heat-Resisting Steels." Compiled by the British Welding Research Association in collaboration with British Chemical Plant Manufacturers' Association, The British Electrical and Allied Manufacturers' Association, Council of British Manufacturers of Petroleum Equipment, The Society of British Aircraft Constructors, Ltd., Stainless Steel Fabricators' Association of Great Britain and The Stainless Steel Manufacturers' Association. With a Foreword by Sir Ben Lockspeiser, K.C.B., M.A., M.I.Mech.E., F.R.Ae.S., F.R.S. 207 pp. inc. appendices, index and numerous illustrations. London, 1953. British Welding Research Association. 27s 6d.

"Equipment for the Thermal Treatment of Non-Ferrous Metals and Alloys." A Symposium on Metallurgical Aspects of the Subject, held in London on the occasion of the Annual General Meeting of The Institute of Metals, March 26th, 1952. Institute of Metals Monograph and Report Series No. 14. 104 pp. London, 1953. The Institute of Metals. 15s. or \$2.50.

"Oxidation of Metals and Alloys." By O. Kubaschewski, Dr.phil.habil., and B. E. Hopkins, M.Sc. 239 pp. inc. indices and numerous illustrations. London, 1953. Butterworths Scientific Publications. 35s. net. By post 1s. extra.

"Progress in Metal Physics"—Vol. 4. Edited by Bruce Chalmers, D.Sc., Ph.D. 403 pp. inc. indices. London, 1953. Pergamon Press, Ltd. 60s.

"The Casting of Non-Ferrous Ingots." By Leslie Aitchison, D.Met., M.Sc., F.R.I.C., F.R.Ae.S., M.I.Mech.E., and Vova Kondic, B.Sc., Ph.D. 370 pp. inc. index and 71 illustrations. London, 1953. Macdonald & Evans, Ltd. 42s.

The Metco Metallizing Handbook. By H. S. Ingham and A. P. Shepherd. 249 pp. Published by Metallizing Engineering Co., Inc., Long Island City 1, N.Y., U.S.A. In Great Britain by Metallizing Equipment Co., Ltd., Chobham.

"Higher Industrial Production with Electricity." Electricity and Productivity Series, No. 1. 146 pp. inc. index and 104 illustrations. London, 1953. British Electrical Development Association. 8s. 6d. net. By post 9s.

METALLURGICAL DIGEST

New Titanium-Boron Alloy Steel

By John L. Everhart

IN addition to their strategic value, ferritic materials have other characteristics which make them attractive for moderately elevated temperature service. These include higher thermal conductivity, lower coefficients of expansion, and greater ease of fabrication than the more highly alloyed austenitic steels: they can also be inspected by magnetic particle methods.

During an investigation undertaken to develop suitable low alloy steels for this service, the high-temperature creep and rupture properties of several steels, including six special ferritic and five stainless steels, were determined. While the chromium-molybdenum and chromium-molybdenum-vanadium steels had the highest strengths of the standard low-alloy compositions in the 800-1,200° F. range, it was found that nitrogen, titanium and boron were more effective in increasing the high-temperature strength of ferritic steels than were the more familiar elements.

An intensive study on 30 lb. laboratory melts of the titanium-boron steels with a number of alloy additions showed that those having a titanium: carbon ratio of 2-4 were superior to those in which the ratio was higher. Creep and rupture strengths at 1,200° F. increased continuously with increasing carbon up to 0.2%, the maximum investigated. Titanium-boron alloys containing 2-3% chromium and 1% molybdenum had the best properties of all the alloys investigated. It was determined that: (1) boron variations from 0.01% to 0.1% had no significant effects on the high-temperature properties at 1,200° F.; (2) molybdenum was most effective in improving the hot strength of the titanium-boron

steels; and (3) chromium provided resistance to scaling and oxidation. It was found in this investigation that tungsten and vanadium added to the 3% chromium-1% molybdenum-titanium-boron steels to a maximum of 0.15%, individually or in combination, gave only a minor improvement in creep and rupture strength.

Using these results as a guide, a 600 lb. commercial heat of 3% Cr-1% Mo-Ti-B steel, having a titanium: carbon ratio of 2, was produced for the investigation of the high-temperature properties. The low titanium: carbon ratio introduced a problem, because it has been determined that high-boron steels which do not contain sufficient titanium to stabilise the carbon have a tendency towards red shortness. By limiting the hot-working temperature to 1,850° F., it was possible to overcome the anticipated trouble, and to forge and roll the alloy into sheet without difficulty. The room temperature tensile properties of the steel were high enough to meet the room temperature requirements for gas turbine wheels.

To develop the desired high-temperature properties in the Cr-Mo-Ti-B steels, suitable heat treatment is necessary. Temperatures must be sufficiently high to austenitise the steel completely and, in addition, allow maximum solution of the

titanium, boron and carbides: thus, the steel must be heated to 1,900-2,100° F. In sheet form, full hardness can be obtained by cooling in air from the normalising temperature.

Creep tests were carried out at several temperatures to determine the rate of deformation as compared with other materials. It was found that for 1% deformation in 50 hours at 1,200° F., the Cr-Mo-Ti-B steel supports a higher stress than any of the annealed stainless steels under the same conditions. For 1% deformation in periods up to 1,000 hours at 1,200° F., this alloy is superior to any of the low-alloy steels investigated and to some of the highly-alloyed steels. Rupture tests gave similar results.

Because of the low alloy content of the Ti-B steels, they are not notably resistant to corrosion or oxidation at high temperatures. At 1,200° F. for periods of several hundred hours, air oxidation is not prohibitive for sheet stock of the 3% Cr-1% Mo-Ti-B composition, but at higher temperatures scaling becomes a significant factor in causing premature failure, and tests were made with ceramic-coated samples to secure protection from oxidation. No superiority in strength was found with these coated samples at temperatures up to 1,200° F. but, at 1,400° F., the coated material was definitely superior to the uncoated sheet.

An evaluation was made of the effect of welding on the high-temperature rupture properties of the 3% Cr-1% Mo-Ti-B steel. Welds were made by the inert-gas-shielded arc process using

TENSILE PROPERTIES OF 600 lb. HEAT OF 3% Cr-1% Mo-Ti-B SHEET

Composition	%	Condition	Tensile Strength lb./sq. in.	Yield Strength lb./sq. in.	Elongation on 2 in. %
Carbon	0.065	Normalised 1,900° F.	127,500	105,000	5
Manganese	0.34				
Molybdenum	1.06				
Boron	0.022	Preheated at 2,100° F., hot-rolled at 1,850° F.	124,000	96,500	7
Silicon	0.28				
Chromium	2.91				
Titanium	0.14		143,000	110,000	9

From *Materials and Methods*, Sept. 1952, 96-98.

COMPARISON OF CREEP AND RUPTURE PROPERTIES OF 3% Cr-1% Mo-Ti-B STEEL at 1,200° F.

Material	Heat Treatment	Stress (lb./sq. in.) for 1% Creep in:				Stress (lb./sq. in.) for Rupture in:			
		1 hr.	10 hr.	100 hr.	300 hr.	1 hr.	10 hr.	100 hr.	300 hr.
3% Cr-1% Mo-Ti-B* .. .	2,100° F. in hydrogen, air-cooled.	50,000	40,500	22,000	15,000	52,100	42,000	28,000	17,500
3% Cr-1% Mo-Ti-B* .. .	Preheated at 2,100° F. Hot rolled at 1,850° F.	—	42,000	23,000	16,000	—	47,000	26,000	18,000
18% Cr-8% Ni .. .	Annealed	17,000	16,500	16,200	16,000	38,000	31,000	21,000	17,000
18% Cr-13% Ni-2% Mo .. .	Annealed	17,000	17,000	17,000	16,500	37,000	33,000	28,000	25,500

* 600 lb. heat.

a copper back-up strip to minimise the formation of a heat tempered zone. Although the welded-joint high-temperature rupture strengths were not equivalent to the parent metal, they were quite high. Since the failures were confined to the weld metal, further investigation of welding

procedures and filler rods might result in improved welds.

The development of these alloys was carried out at the Cornell Aeronautical Laboratory in collaboration with the Research Laboratory, Titanium Alloy Manufacturing Division, National Lead Company.

Hafnium Metal—Its Properties and Future

By John L. Everhart

A SERIES of new metals has been produced in ductile form in recent years. Some, like titanium and zirconium, have reached the commercial stage, others are just leaving the laboratory. Among the latter is hafnium, a metal isolated 30 years ago, a laboratory curiosity two years ago, and now in production by the iodide process in rods weighing up to 12 lb.

Hafnium and zirconium occur together in ores, the hafnium content of the ore generally ranging from 0.2 to 15% of the zirconium content. Many of the properties of hafnium and zirconium are similar, and separation is difficult but can be accomplished by chemical means. After such separation, metallic hafnium is obtainable by the methods which are used for zirconium: that is by the iodide and Kroll processes. Iodide hafnium contains less than 1% zirconium and, like zirconium, it combines with all the noble gases. Oxygen dissolves in the metal, and, in sufficient quantities, makes it permanently brittle. Since hafnium is so reactive no deoxidisers are known, and careful melting practice is necessary to obtain ductile material. The crystal bar obtained in the iodide process can be melted in an arc furnace under argon to obtain massive hafnium suitable for further working. When the metal has been obtained in massive form, the rate of oxidation is sufficiently low to permit

hot working in air, and, by a combination of hot and cold working, the metal has been produced in the form of sheet and wire.

Some of the properties of iodide hafnium are given in Table I which also includes properties of zirconium and titanium for comparison.

Little information is available on the mechanical properties of hafnium. The crystal bar has a hardness, as deposited, of about Rockwell B78, and after arc melting and annealing, the material has about the same hardness. In a material which has been cold-worked to 60% reduction, the Rockwell B hardness increases to 102.

The oxidation resistance is important for determining suitable conditions for hot working and possibly for high temperature service. Tests made in still air showed that at 1,380° F. hafnium and zirconium oxidised at approximately the same rate, but at 1,650° F. the rate of oxidation of hafnium was only about half that of zirconium.

The corrosion resistance of hafnium is still under investigation. In general, its resistance to mineral acids more nearly resembles titanium than zirconium. All three materials are approximately equally resistant to 10% sulphuric acid, while hafnium is superior to the others in resistance to a one-to-one mixture of hydrochloric and sulphuric acids. The three metals show excellent resistance to a 20% sodium chloride solution, although

hafnium is the least resistant of the group. In its resistance to 50% sodium hydroxide, hafnium is superior to titanium but inferior to zirconium, which shows no weight loss under the conditions of the test. These initial results indicate that hafnium has promising characteristics for use in corrosive environments, although probably only in specialised applications, since the metal is likely to be available in limited quantities only.

The crystal structure of hafnium is similar to that of magnesium. It can be hot worked in air at 1,650° F. without protection, and it should be possible to hot forge the metal by procedures similar to those employed with zirconium. The crystal structure changes at 2,400° F. from hexagonal close packed (the room temperature modification) to body centered cubic. This transformation is similar to that which occurs in zirconium at 1,580° F. and in titanium at 1,625° F. Thus, the room temperature modification of hafnium is stable to much higher temperatures than that of zirconium and titanium.

Cold-worked hafnium can be completely recrystallised by heating to 1,435° F. Annealing should be carried out at a somewhat higher temperature, for example, 1,550° F. The rate at which oxygen is absorbed is sufficiently low to permit annealing operations on heavy sections to be carried out in air. For very light sections, annealing in a protective atmosphere is preferable.

As occurs with the introduction of each new metal, suitable applications appear only after its characteristics have been fully evaluated. Up to the present time, no commercial applications have been developed for hafnium except in the atomic energy programme, where specific applications have not been revealed. It has been suggested for use in electronic tubes; and alloys of hafnium containing copper, silver and nickel have been produced by powder metallurgy methods.

Institute of Welding Larke Medal Award

The Council of the Institute of Welding has awarded the Sir William J. Larke Medal for 1952 to Mr. J. Rannie, M.Sc., M.I.N.A., for his paper "Shipyard Changes with Special Reference to Steelwork Construction in Oil Tankers." Mr. Rannie is Welding Engineer to John Brown & Co., Ltd., of Clydebank.

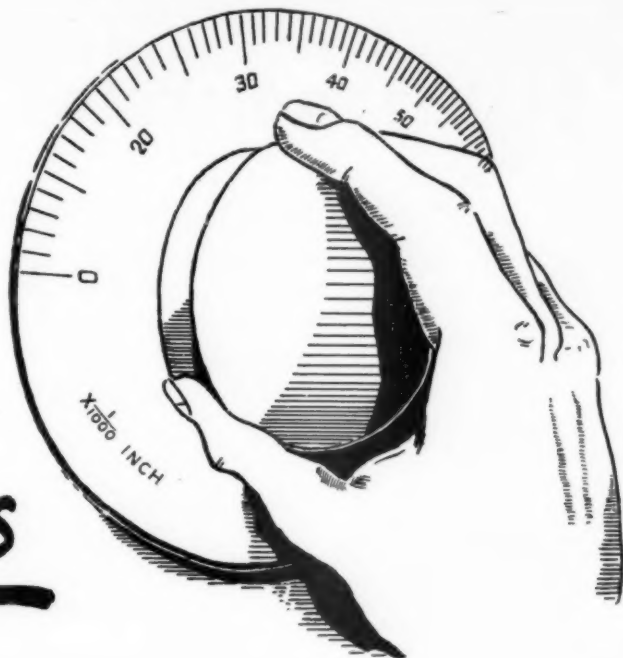
From *Materials and Methods*, November, 1952, 95-97.

TABLE I.—COMPARATIVE PROPERTIES OF HAFNIUM, ZIRCONIUM AND TITANIUM.

	Hafnium	Zirconium	Titanium
Density—lb./cu. in.	0.47	0.24	0.16
Melting Point—°F.	3,590	3,355	3,140
Thermal Conductivity—B.t.u./sq. ft./ft./hr./°F. at 212° F.	—	9.6	8.1
Coefficient of Expansion per °F. at 70° F.	3.4×10^{-6}	3.1×10^{-6}	5.0×10^{-6}
Specific Heat—B.t.u./lb./°F.	0.035	0.069	0.13
Electrical Resistance—Microhm-cm.	30	40	60
Electrical Conductivity—% I.A.C.S.	5.7	4.3	3.1
Modulus of Elasticity in Tension—lb./sq. in.	20,000,000	14,000,000	15,000,000

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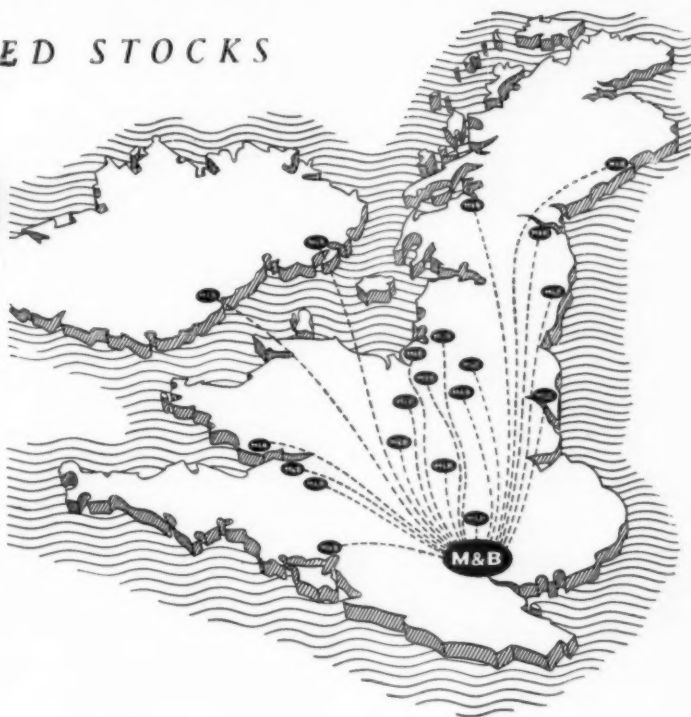
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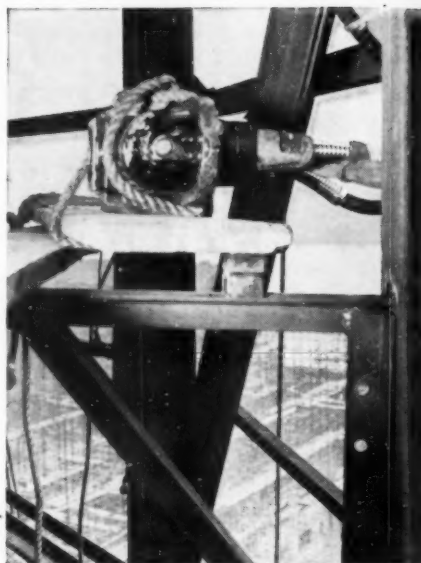


Illustration shows Newton Victor Raymax 140 kV. Industrial X-ray Unit lashed in position for radiography of welds during construction of the welded heat-storage tower for the Pimlico District Heating Scheme.
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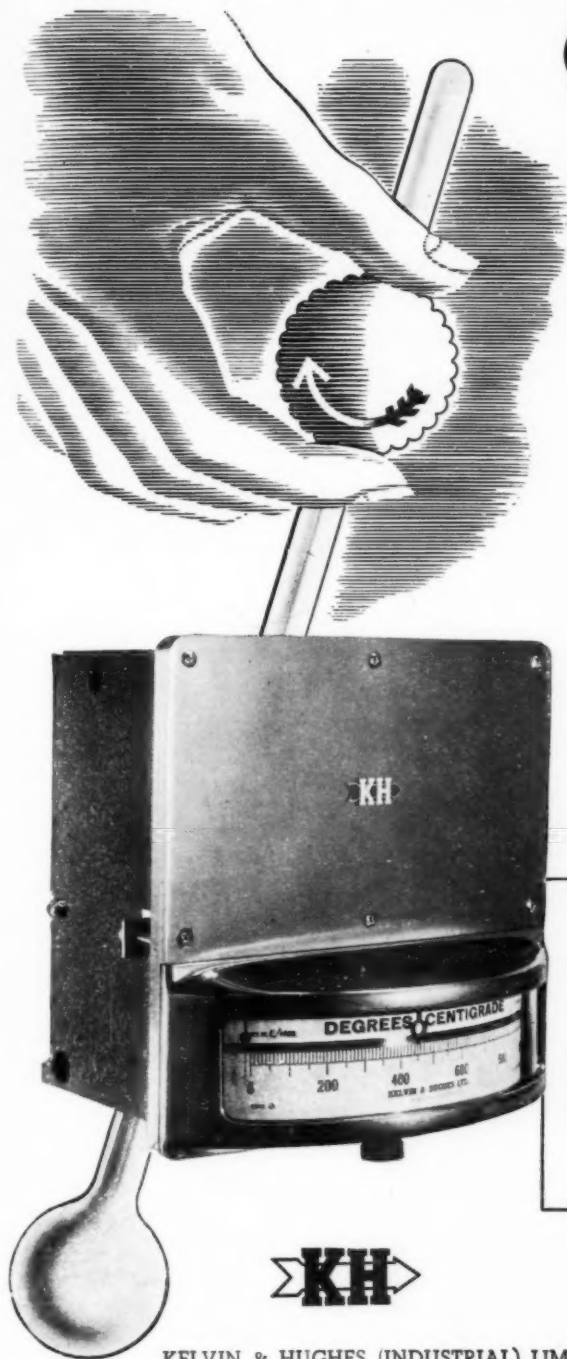
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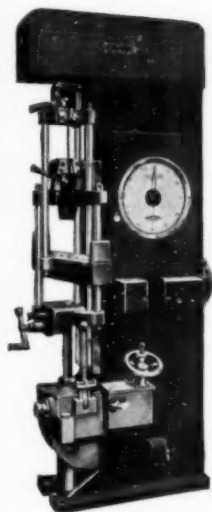
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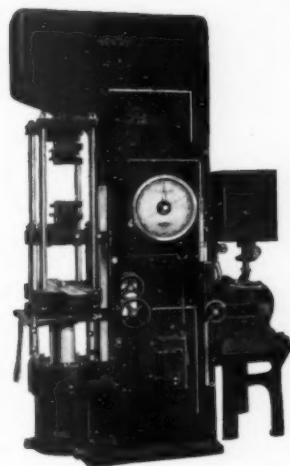


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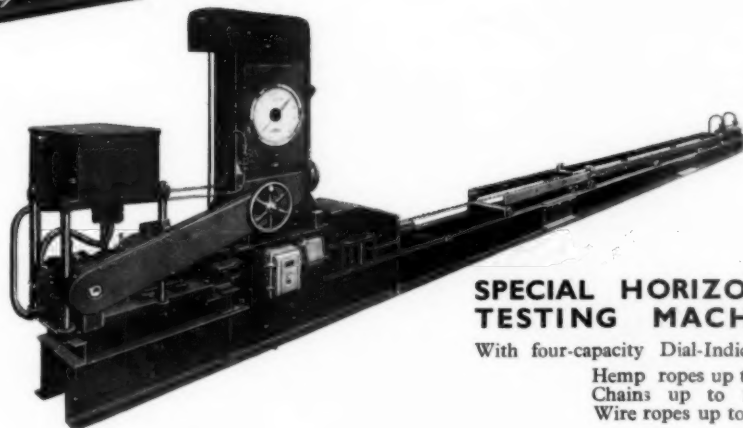
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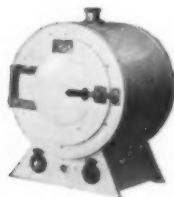
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INSTRUMENTS AND MATERIALS

MARCH, 1953

Vol. XLVII, No. 281

The Electrochemical Analysis of Silver Solder

By R. W. C. Broadbank and B. C. Winram

School of Chemistry, College of Technology, Leicester.

In order to speed up the chemical analysis of silver solders a method is proposed based on the electro-deposition of the individual metals at the appropriate voltages from perchloric acid solutions. The accuracy of the method is claimed to be sufficient for routine purposes.

THE chemical analysis of brazing solders containing silver, copper, cadmium and zinc is not an easy task. Silver can be estimated conveniently by titration with thiocyanate or precipitation as chloride, and copper by the liberation of iodine from potassium iodide or by precipitation as thiocyanate. Cadmium and zinc, however, are more difficult to determine.

Precipitation of cadmium sulphide in the presence of slightly ammoniacal cyanide (after the removal of silver as chloride and precipitation of copper and cadmium sulphides from acid solution) followed by conversion to sulphate is a tedious operation. It involves the use of relatively large amounts of cyanide, and the cadmium is precipitated in a finely divided form, resulting in slow filtration. Also, a complete separation of cadmium from copper and zinc is difficult to achieve by a single precipitation.

Alternatively, silver may be removed as chloride, copper by means of iron wire, and cadmium precipitated as the phenyltrimethylammonium iodide complex $(\text{PhMe}_3\text{N})_2(\text{CdI}_4)$. This is dissolved in ammonia, acidified with hydrochloric acid and titrated with iodate in the presence of cyanide. This method, although easier to manipulate than the previous one, is by no means simple.

Methods involving electro-deposition offer an immediate advantage. Silver may be precipitated as chloride and either weighed as such or re-dissolved in cyanide solution and deposited electrolytically. After removing chlorides from the filtrate by fuming with sulphuric acid, diluting and adding a little nitric acid, copper may be deposited and weighed as such. Cadmium can be separated from zinc by precipitation, with hydrogen sulphide, from sulphuric acid solution. This separation, however, may not be complete, and re-precipitation (from sulphuric acid solution) may be necessary. Cadmium sulphide precipitated under such conditions is in a relatively coarse form, and is quite easily filtered. After dissolving the sulphide precipitate in hydrochloric acid, making alkaline with potassium hydroxide and adding sufficient cyanide to clear the solution, cadmium may be deposited by electrolysis. Finally, zinc is determined by precipitation as sulphide followed by ignition to oxide, or by electro-deposition from alkaline solution.

This process, however, is still time-consuming, and a more rapid method has been developed by Norwitz.¹ Silver is separated by electro-deposition from sodium-nitrite/nitric-acid medium, and after destroying the nitrite by boiling, copper is deposited. The solution is fumed with sulphuric acid, diluted and cadmium deposited. Zinc is then plated out in the usual way from alkaline solution.

It occurred to the authors that the deposition voltages (from acid solution) of the four metals are sufficiently far apart for their separation to be feasible without the necessity for the rather complicated apparatus used in electrochemical analysis with graded cathode potential. The following work was, therefore, carried out with a view to developing a simple method for the analysis of silver solder, using apparatus readily available in the average works laboratory.

Experimental

In this work a Griffin and Tatlock Electrochemical Analysis Apparatus was used, direct current being supplied to the electrodes by means of a variable transformer and rectifier. Sufficient control on the applied voltage was obtained by using this apparatus with a voltmeter connected across the terminals. Platinum electrodes were used throughout, but were plated with copper prior to the deposition of cadmium and zinc.

The first experiments were carried out using "synthetic alloys" made up from weighed amounts of silver nitrate, copper sulphate, cadmium sulphate and zinc sulphate, all of "Analar" quality. It was found, however, that the last three of these salts were unsuitable, as the water of crystallisation did not always coincide exactly with the formula amounts. In subsequent experiments, therefore, electrolytic copper and "Analar" zinc were used. The only convenient source of cadmium available, however, was the sulphate, $3\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$, and this was employed after its cadmium content had been determined chemically.

The deposition voltages of the metals concerned, under the appropriate working conditions, were determined simply by electrolysis of the solutions and observing the voltages at which deposition commenced.

¹ *Metallurgia*, 1951, **44**, 276.

The first electro-separation of copper, cadmium and zinc was attempted from N/2 sulphuric acid solution in the presence of a little gelatin. Copper was separated at 2.3 volts, using a fairly rapidly rotating anode (approximately 600 r.p.m.). Cadmium was then plated out at 3.4 volts, again using vigorous stirring. At voltages above 3.6 (and even below this if the stirring was not sufficiently rapid) zinc was deposited to a certain extent. The cadmium deposit tended to be rather powdery, but nevertheless stood up to careful washing, drying and weighing. Little improvement resulted from the addition of more gelatin, and this had the disadvantage that frothing became excessive. After the removal of copper and cadmium, the solution was made alkaline and electrolysed for zinc in the usual way.

The weights of the deposits thus obtained were in reasonable accord with the theoretical values. There seemed, then, to be no reason why silver solder should not be analysed by dissolution in nitric acid, removal of silver (e.g. as chloride or, possibly, by electrolysis), followed by evaporation, removal of other acid radicals by heating with sulphuric acid, dilution and electrolysis as described.

Silver is not deposited in a convenient form from nitric acid alone, but it was found that by adding a little gelatin and electrolysing at approximately 60°C., a reasonably coherent deposit could be obtained from 5% nitric acid solution. Synthetic alloys of copper, silver, cadmium and zinc were then analysed quite rapidly and fairly successfully.

The most difficult and time-consuming operation in the process was the evaporation of the solution and decomposition of the nitrates by heating with sulphuric acid, prior to the electrolysis for copper. Almost always there was a marked tendency towards spitting, which necessitated constant attention. It was decided, therefore, to try the effect of substituting perchloric for sulphuric acid.²

The constituents of a synthetic alloy were weighed out, dissolved in 4 ml. nitric acid (S.G. 1.42) and 10 ml. water. Nitrous fumes were boiled off, the solution diluted to about 60 ml., gelatin added, and silver electro-deposited at 60–70°C. and 1.2 volts. After evaporation of the solution to low bulk, 10 ml. of 72% perchloric acid were added, and nitrates expelled by heating. The solution was diluted to about 100 ml. and electrolysed at 2.3 volts with a rapidly rotating anode (circa 600 r.p.m.). When removing the cathode prior to weighing, the voltage had to be reduced to about 2 before stirring was stopped, or cadmium began to deposit. The copper deposit was washed, dried and weighed. A little gelatin was added, and cadmium deposited at 3.3 volts, again with rapidly rotating anode. Finally the solution was made alkaline with sodium hydroxide, and electrolysed for zinc.

This method was, in our opinion, a marked improvement on that using sulphuric acid. No tendency towards spitting was observed during the fuming prior to the deposition of copper. The deposits of copper and cadmium were quite hard and bright, and eminently suitable for washing, drying and weighing. Results, too, were in excellent agreement with those calculated.

	Found	Calculated
Silver	0.5049 g.	0.5052 g.
Copper	0.1629 g.	0.1628 g.
Cadmium	0.2836 g.	0.2835 g.
Zinc	0.2145 g.	0.2150 g.

² See Osborn, G. H., *Metallurgy*, 1949, 39, 111.

A sample of Easyflo solder was then successfully analysed by the same method.

The possibility then suggested itself that silver, too, may be deposited in suitable form from perchloric acid solution and, if so, that the method may be made still more rapid. Accordingly, a sample was dissolved in the least possible quantity of nitric acid, perchloric acid added and the solution heated till nitrates were expelled. Upon dilution and electrolysis at 1.2 volts (0.25 amp.) silver formed a coarse coherent deposit, quite suitable for washing, drying and weighing. The addition of gelatin was unnecessary (it was subsequently found that gelatin was not necessary in the deposition of cadmium). It was, however, found that if the concentration of perchloric acid was greater than about 7% v/v, results were unreliable.

Final Procedure

The final procedure adopted was as follows:

(1) Dissolve 0.5–1 g. sample in 5 ml. of 1:1 nitric acid and boil off nitrous fumes. Add 5 ml. perchloric acid (72%), evaporate to fuming and heat till nitrates are decomposed. Cool, dilute to about 100 ml. and deposit silver at 1.2 volts (current about 0.25 amp.) with stirring (about 200 r.p.m.). When deposition is complete, the voltage tends to rise and the current to fall.

(2) Add a further 5 ml. perchloric acid and deposit copper, with vigorous stirring (approximately 600 r.p.m.) at 2.2 volts (current approximately 0.75 amp.). When the cathode is removed prior to drying and weighing, the voltage must be reduced to 2 before stirring is stopped—otherwise cadmium will begin to deposit.

(3) Deposit cadmium at 3.4 volts with vigorous stirring—again reducing the voltage before stirring is stopped prior to removal, washing, drying and weighing of the cathode.

(4) Finally, add an excess of sodium hydroxide (any turbidity of the solution may be cleared with a little cyanide) and electrolyse for zinc in the usual way. The complete analysis can be carried out in a total time of 4 to 4½ hours.

Using this procedure, the following results were obtained, for a sample of Easyflo solder, by three operators working independently:

	Chemical Analysis	B.C.W.	R.W.C.B.	J.E.E.
Silver % ..	50.0	50.0	49.9	50.0
Copper % ..	15.5	15.5	15.5	15.4
Cadmium %	17.9	17.8	17.9	18.0
Zinc % ..	16.6*	16.6	16.6	16.6
		99.9	99.9	100.0

* By difference.

Analyses are reported to only three significant figures since beyond this, in our opinion, a higher accuracy is implied than ordinary methods are capable of yielding.

A warning should be given that if the deposition of one metal is incomplete, not only will the result for that metal be low, but that of the following one will be correspondingly high. The fact that the results total 100% cannot alone be taken to indicate that the figures obtained are correct.

A sample of Silfos solder has also been analysed by a similar method. The alloy was dissolved in nitric acid, fumed with perchloric acid, and silver and copper

determined as described. Phosphorus was determined by precipitation from the remaining solution with magnesia mixture, in the usual way, and ignition to magnesium pyrophosphate.

	Expt. 1	Expt. 2	Chemical Analysis
Silver %	15.1	15.2	15.1
Copper %	79.8	79.9	79.9
Phosphorus % ..	5.1	5.1	—
	100.0	100.2	

Conclusion

Silver, copper and cadmium may be determined, in

silver solder, rapidly and with sufficient accuracy for routine purposes, by electro-deposition at the appropriate voltages from perchloric acid solution. No apparatus is required beyond that readily available in the average works laboratory.

This method has been used for the analysis of Easyflo and Silfos solders.

Acknowledgments

The authors would like to express their appreciation to Mr. R. Adkins, Chief Works Chemist, and to members of the Works Laboratory of the B.T.H. Co., Ltd., Rugby, for their interest in this work.

Rapid Determination of Bismuth, Copper and Lead in Aluminium Alloys by Electrodeposition

By George Norwitz

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IN an earlier paper, the author proposed an improved method for the determination of bismuth, copper and lead in aluminium alloys.¹ This method, although more rapid than previous methods^{2, 3} is still rather long, since it requires filtrations and evaporations. In the present paper, the author proposes an extremely rapid electrolytic method for the determination of bismuth, copper and lead in aluminium alloys that entirely eliminates the necessity for filtrations and evaporations. In the proposed method, the copper is separated from the bismuth and lead by the use of a nitric acid medium containing hydrogen peroxide.⁴ The copper and bismuth are deposited together from a nitric-phosphoric acid medium, and the copper, bismuth and lead are deposited together from a hydrochloric acid medium containing hydroxylamine hydrochloride. By the use of simple subtraction the percentage of copper, bismuth and lead in the sample is readily obtained. For the amount of bismuth found in commercial aluminium alloys (less than 0.75%) there is no danger of the bismuth precipitating as bismuth phosphate from the nitric-phosphoric acid medium.

Procedure

Dissolve a 1 g. sample in 22 ml. of sodium hydroxide solution (15%) by heating on the steam bath. Dilute to 100 ml. with hot water and add 35 ml. of nitric acid (1 to 1) with stirring. Cool and dilute to 150 ml. Add 30 ml. of hydrogen peroxide (3%) and electrolyse for 30 minutes at 2 amp./sq. dm. Add 10 ml. of hydrogen peroxide (3%) at the end of 15 minutes and another 10 ml. of hydrogen peroxide (3%) at the end of the electrolysis. Immerse the cathodes in water and in alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as copper.

Dissolve a 1 g. sample in 22 ml. of sodium hydroxide solution (15%) by heating on the steam bath. Dilute to 100 ml. with hot water and add 35 ml. of nitric acid (1 to 1) with stirring. Cool and dilute to 190 ml. Add 3 ml. of phosphoric acid and electrolyse for 30 minutes

TABLE I.—RESULTS FOR BISMUTH, COPPER AND LEAD IN TWO REPRESENTATIVE ALUMINIUM ALLOYS

Sample	Contains*	Found
1	0.53 Bi	0.50 Bi
	0.51 Pb	0.53 Bi
	5.51 Cu	0.53 Pb
		5.48 Cu
2	0.50 Bi	0.48 Bi
	0.54 Pb	0.48 Bi
	5.62 Cu	0.52 Pb
		0.53 Pb
		5.63 Cu
		5.59 Cu

* Determined by A.S.T.M. umpire method (2).

at 2 amp./sq. dm. Immerse the cathodes in water and in alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as copper plus bismuth. Deduct the weight of the copper to obtain the weight of the bismuth.

Dissolve a 1 g. sample in 30 ml. of hydrochloric acid (1 to 1). Add 15 ml. of hydrogen peroxide (3%) and boil to dissolve the copper and destroy the peroxide. Dilute to 190 ml. with hot water and add 8 g. of hydroxylamine hydrochloride. Heat to boiling and boil about 2 minutes. Electrolyse the hot solution for 30 minutes at 2 amp./sq. dm. Immerse the cathodes in water and in alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as copper plus bismuth plus lead. Deduct the weight of copper plus bismuth to obtain the weight of lead.

The results obtained by the author for two samples are shown in Table I.

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- 2 American Society for Testing Materials, "A.S.T.M. Methods of Chemical Analysis of Metals," p. 149, Philadelphia, Pa., 1946.
- 3 Norwitz, G., Greenberg, S., and Bachtiger, F., *Analytical Chemistry*, **19**, 173 (1947).
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Rapid Gas Analysis by Dynamic Method

A New Apparatus Using Soap Film Technique

By using a dynamic method of gas analysis, results which formerly took an hour or more to obtain are now available in a few minutes. The apparatus used, which incorporates a number of soap film meters, is described, together with its mode of operation.

THE major disadvantage of the static method of gas analysis, in which gas constituents are consecutively removed from one representative sample and the residual gas volumes measured, is the fact that a complete analysis of town's gas or a gaseous mixture of similar composition may take from an hour to an hour-and-a-half and a check analysis just as long; moreover, the full attention of a skilled analyst is required throughout.

Barr's description¹ in 1934 of an apparatus embodying a moving soap film for calibrating gas flowmeters was followed in 1936 by some work of Gooderham² showing that soap films could be used to define gas volumes. Later developments led to the use as meters of calibrated glass tubes through which the passage of a soap film was timed with a stop-watch³. More recently, the stop-watch was discarded and the method embodied in a new apparatus⁴. Still further improvements^{5,6} led to the dynamic or streaming apparatus now manufactured by Griffin and Tatlock Ltd., under licence from The North Thames Gas Board (formerly The Gas Light and Coke Co. Ltd.). With this equipment, which may be operated by unskilled personnel after brief instruction, the average time for an analysis of town's gas, after an initial period of flushing, is three minutes.

Basis of the Apparatus

The basic principle of the streaming method is to pass gas through an accurate gas meter; to remove one constituent; to pass the gas through a second accurate

gas meter; to remove another constituent, and so on. The gas meters use a soap film, and the sizes and graduations on the soap film meters are designed to suit the appropriate gases under test and to give a degree of accuracy of about $\pm 0.1\%$.

A typical "meter-scrubber-meter" unit is shown diagrammatically in Fig. 2. In this unit the streaming gas sample enters under constant pressure at *K*. Via stopcock *S*, it may travel to the scrubber *N* by tube *M*. Alternatively, by turning *S* through 90°, it may travel via *L* to the calibrated tube or meter. Compression of the rubber teat *P* at the base of the meter causes a soap film to be formed across the tube, and this film is pushed up the whole length of the meter by the gas advancing down *L*. A measured volume of gas thus passes up the scrubber *N* against a counter current of liquid reagent, which removes one constituent. The residual gas flows via *K*¹ to the second gas meter where its volume is measured.

By extending the units, a complete analytical system is built up of meters and scrubbers in series, each scrubber being charged with an absorbent specific for a given constituent of the gas. All the reactive constituents are removed leaving only the inerts. From the change in volume, i.e., relative movement of the soap films in successive meters, the percentage of each constituent can be read off or easily calculated.

Mode of Operation

The flow diagram of the G.L.C. (Gooderham) Soap Film Gas Analysis Apparatus is shown in Fig. 3. Gas enters the apparatus at inlet *A* and, if at a pressure exceeding $\frac{3}{4}$ -1 in. water, passes directly through a two-way stopcock to a constant pressure regulator 15 charged with dibutyl phthalate, and thence to the system, under a pressure *h*. Excess gas either bubbles to the outside atmosphere through tube *B* or is burned. If the pressure of the gas is insufficient, it is boosted by the adjustable compressor *C*. In this case, the stopcock of pressure regulator 15 is turned through 180°, tap *G* acting as an additional bleed-off. The gas passes from 15 through a control capillary 17, its by-pass tap being closed, and enters saturator 14. This contains a spill of blotting paper fed from water in the bulb at the base; the top is fitted with a C10 joint cap and the base terminates in a drain tap. Thence the saturated gas passes through the two-way stopcock 18 to the first soap film gas meter 1, and the first scrubber 9. This scrubber consists of a glass tube 46 cm. long \times 6 mm. bore, containing a glass helix which is a sliding fit; at the base it is formed into a U-tube which acts as a gas seal and allows spent reagent to overflow into the collecting bottle *F*. The gas flows upwards through 9 against a counter-current of potassium hydroxide solution delivered under a constant head *k* through siphon 37, fitted with a B10

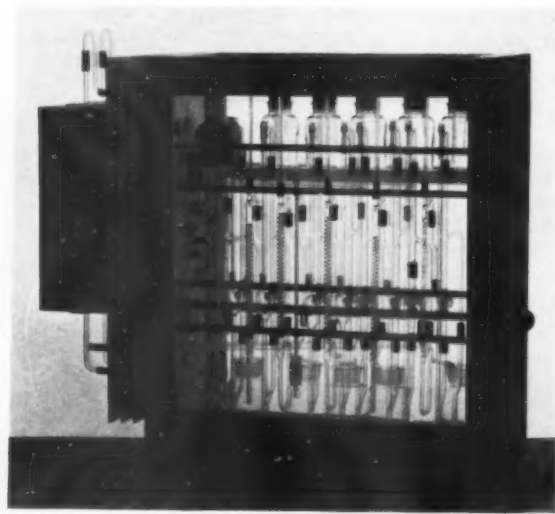


Fig. 1.—The G.L.C. (Gooderham) soap film gas analysis apparatus.

cap 38, from reagent bottle *D*. The flow rate of the reagent is controlled by the fine inlet capillary 41, which governs the rate of air admission into *D*. The potassium hydroxide solution removes carbon dioxide, and the residual gases pass through the next stopcock 18 in the system to gas meter 10.

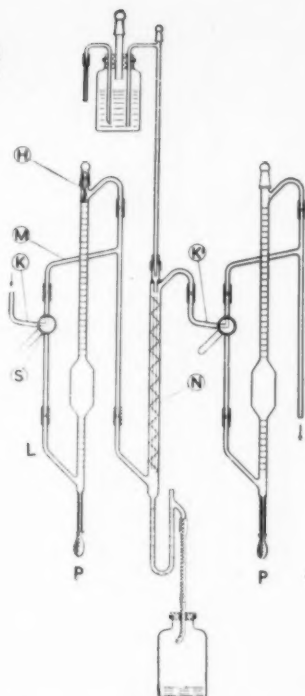
In scrubber 10 the oxygen is removed by a solution of acidified chromous chloride. Thence the gas passes via tap 18 to meter 3 and scrubber 11, where unsaturated hydrocarbons are removed by activated sulphuric acid. Next, the residual gases, now free from water vapour, are passed through a second saturator 14 and thence via tap 18 to meter 4 and the Pyrex glass combustion pipette 43. The latter is packed with copper oxide made from wire, and is enclosed in an electrically heated furnace 53a operating from an A.C. mains supply and maintained at 270° C. by means of a Simmerstat control: the packed tube is fitted at the base with a U-tube 27 to collect water from the oxidation of hydrogen and to act as a gas seal when water-filled.

The gas then passes via stopcock 19 to meter 5 and scrubber 12 where the carbon monoxide, now oxidised to carbon dioxide, is removed with potassium hydroxide solution.

The remaining gases then pass via tap 18 to meter 6 and a second, silica, combustion pipette 44, where the saturated hydrocarbons are oxidised to water and carbon dioxide. This pipette is packed with Arneil catalyst, and is maintained at 600° C. The carbon dioxide is removed by potassium hydroxide solution in scrubber 13 after the gas has been measured in meter 7. Only inert gases are left to be measured in meter 8 and to escape to atmosphere by outlet 45.

Thus, of the eight meters, No. 1 meters the initial gaseous mixture flowing; Nos. 2, 3 and 4 meter the resultant flow after removal of carbon dioxide, oxygen and unsaturated hydrocarbons respectively; No. 5 meters the flow after hydrogen has been oxidised; No. 6 meters the removal of a volume of carbon dioxide equal to that of the carbon monoxide constituent; No. 7 meters the increase in volume caused by the oxidation of the saturated hydrocarbons other than methane to

Fig. 2. — Typical "meter-scrubber-meter" unit.



CO_2 and H_2O ; and finally, No. 8 meters the residual inert gases after removal of CO_2 by scrubber 13.

While designed primarily for the analysis of town's gas of low nitrogen content, the apparatus may be set up, by the use of appropriate gas film meters, for other gaseous mixtures of widely differing composition⁷. Typical percentage analyses have given the results shown in Table 17.

A minimum volume of 1,500–2,000 ml. is sufficient to flush out the apparatus and to carry out several analyses.

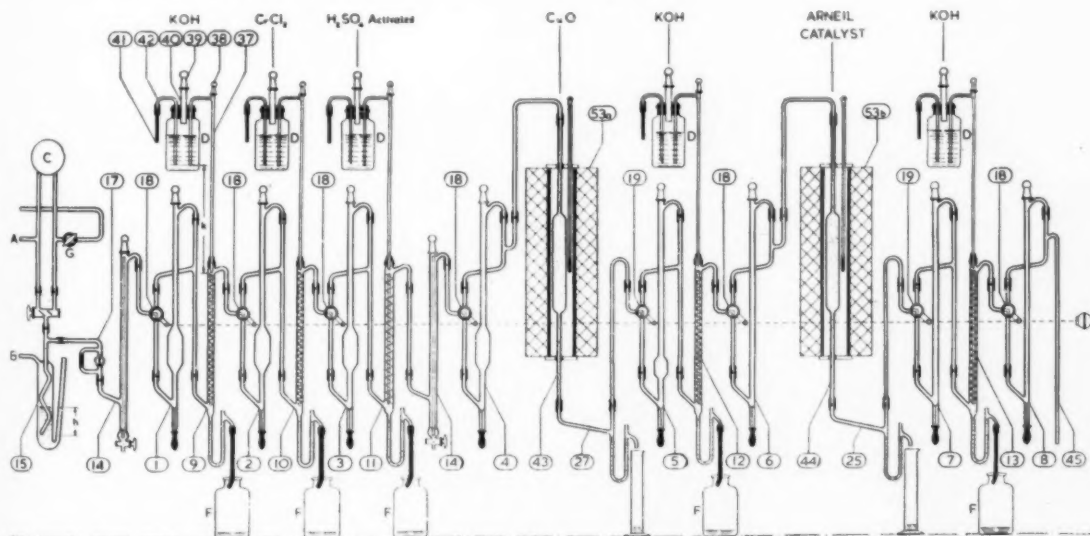


Fig. 3.—The flow diagram of the G.L.C. (Gooderham) soap film gas analysis apparatus.

TABLE I.—TYPICAL GAS ANALYSIS RESULTS.

Gas	CO ₂ %	O ₂ %	C ₂ H ₄ %	H ₂ %	CO%	C ₂ H ₂ %	CH ₄ %	N ₂ %
Blast furnace..	9.3	0.0	0.0	4.1	20.4	0.0	2.1	55.1
Eucalyptwood..	35.3	0.0	2.1	2.4	37.7	3.0	18.3	1.2
Brown coal ..	42.1	1.4	1.7	8.6	17.5	3.8	18.9	5.9

Advantages of the Method

Among the advantages claimed for this apparatus are the following: the accuracy is at least equal to that of any other known method; results are obtained quickly; no mercury being used, it is possible to utilise reagents that attack mercury; there is no appreciable dead space; no temperature corrections are required and there being no appreciable back pressure no pressure

corrections are necessary; no errors arise from rubber tubing absorption of gases; breakages should be negligible since, once the reagent bottles are filled, glass parts are untouched by hand; full use is made of standard ground glass joints; troubles from reagent attack upon stopcocks or and taps their lubricants are eliminated; revivification of solid reagents can be carried out overnight; the apparatus can be conveniently worked by a seated operator.

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- 1 Barr. *J. Sci. Instr.*, 1934, **11**, 324.
- 2 Gooderham and The Gas Light and Coke Co. Ltd. B.P.489, 117.
- 3 Gooderham. *J. S. C. I.*, 1940, **50**, 1; *Chem. and Ind.*, 1940, **18**, 368.
- 4 Gooderham and The Gas Light and Coke Co. Ltd., R.P. 550, 323.
- 5 Gooderham. *Analyst*, 1947, **72**, 520.
- 6 Gooderham. *Anal. Chim. Acta*, 1948, **2**, 452.
- 7 Donnelly and Broadbent. *J. S. C. I.*, 1950, **60**, 527.

The Physical Society Exhibition

THE 37th Annual Exhibition of Scientific Instruments and Apparatus, organised by the Physical Society, will be held at the Imperial College of Science and Technology, Imperial Institute Road, London, S.W.7, from Monday, April 13th, to Friday, April 17th, 1953. A return has been made to the practice of former years of locating the whole of the exhibition in the main building of the College and this should be of great convenience to visitors.

The hours of opening are: Monday, 2 p.m. to 8 p.m.; Tuesday to Thursday, 10 a.m. to 8 p.m.; and Friday, 10 a.m. to 5 p.m. Admission tickets which may be obtained from the Exhibition Secretary, 1, Lowther Gardens, Exhibition Road, London, S.W.7, are split into four groups: (1) whole day tickets for use on Monday or Friday; (2) whole day tickets for use Tuesday, Wednesday or Thursday; (3) morning tickets for use any one morning (Tuesday to Friday); and (4) evening tickets for use any one evening (Monday to Thursday).

With the penetration of instruments into almost every field of technology, it can safely be said that the scientific visitor, no matter what his field of interest, will find much to interest him. Following the normal policy of the Society, the great number of exhibits appeals primarily to physicists and much new and original equipment will be on show.

As in previous years, the comprehensive Handbook of the Exhibition will be available at the Exhibition, and copies can be obtained on application to the Secretary-Editor of the Physical Society at Lowther Gardens. The price of the publication is 6s. (by post 7s. 3d.).

Summer School and Conference

Theory of Plastic Deformation

THE H. H. WILLS Physical Laboratory and the Department of Adult Education of the University of Bristol, in co-operation with The Institute of Physics, will be conducting a short Summer School followed by a Conference on "The Theory of the Plastic Deformation of Metals, with Special Reference to Creep and to Fatigue," from July 13th to 16th, in Bristol. The provisional programme of the course, which will precede the conference, includes lectures by Professor N. F. Mott, Dr. A. J. Forty and Dr. F. C. Frank. The course is similar in conception to those held in the University of Bristol on this and similar subjects; it is intended mainly for research students at universities and for

members of the staffs of government and industrial laboratories. The particular aim is to see to what extent the observed phenomena can be explained in terms of present theories, and to guide future work.

The fee for the Summer School, which will be on July 13th and 14th, is £1 10s., but there will be no fee for the Conference. Further particulars and forms of application, to be returned before May 31st, can be obtained either from the Director of the Department of Adult Education, The University, Bristol, 8, or from the Secretary of The Institute of Physics, 47, Belgrave Square, London, S.W.1.

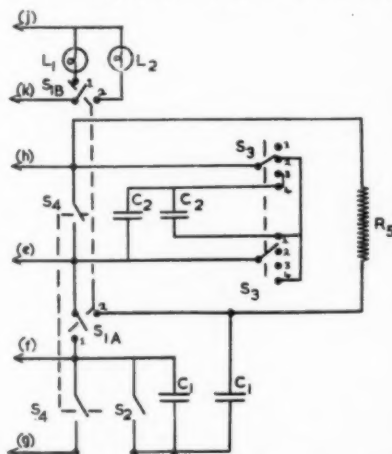
Correspondence

DERIVATIVE POLAROGRAPHY—A Correction

The Editor, METALLURGIA.

Dear Sir,

We regret that there was an error in Fig. 5 (c) of our paper "Modification of the Cambridge Polarograph for Derivative Polarography" (Sept. 1952 issue, p. 158).



Switches S_4 and S_2 should only be connected at the level of connection (f); the line connecting them at the level of connection (g) should be omitted. S_3 , and the two condensers C_1 , should still be connected at level (g). The correct circuit diagram is shown above.

Yours faithfully,

P. R. POMEROY, R. A. WHITE.

The British Non-Ferrous Metals Research Association.
London 13.2.53.

